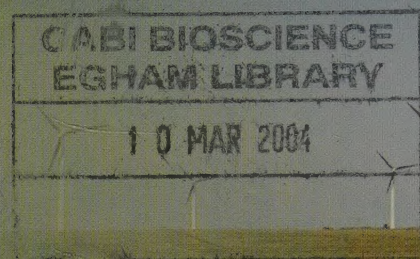


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Renewable Agriculture and Food Systems

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Renewable Agriculture and Food Systems provides an international forum for original research and review articles on the biological, physical, social science, and policy aspects of alternative agriculture and food systems, focusing on the effective use of renewable resources and biodiversity in agro-ecosystems. The journal particularly welcomes multidisciplinary, holistic, systems research that addresses the multiple challenge of economically meeting basic human needs for food, fiber, and energy while maintaining essential natural and environmental resources.

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Editorial

I am pleased to introduce the inaugural issue of **Renewable Agriculture and Food Systems**. The title and new cover reflect the transition to an agriculture that utilizes food production and distribution systems relying less on non-renewable petrochemical resources and more on renewable resources from the sun for food, fiber, and energy needs. Papers in the March issue illustrate this transition. Nazarko et al. demonstrate the potential for broad adoption of 'Pesticide Free Production' for mixed crop farming in Manitoba, Canada, particularly where farmers are offered a flexible framework for transition to reduced pesticide use. In northern Europe, increasing the use of forage legumes in livestock systems can produce higher profits than grass-based systems using high levels of nitrogen fertilizer. However, widespread adoption of forage legumes will depend on technological developments that reduce the risks associated with more difficult establishment and higher nitrate leaching of forage legumes as compared to grass swards. In the northern US Great Plains, weed control problems in no-till wheat-fallow systems led to development of a planning tool for diversifying and integrating crop choices with ecologically-based weed management. Interactions with organic producers of the Northern Plains Sustainable Agriculture Society were instrumental in development by USDA of this tool which can reduce herbicide inputs by 50% for Northern Great Plains producers. The synergistic value of varying viewpoints was realized when organic farmers reviewing this paper questioned the non-target effects of this weed management approach; the author consequently discovered that the enhanced crop diversity proposed would also provide collateral benefits for non-chemical disease and insect control.

Several articles in this issue demonstrated that, in addition to the environment, economic and social factors in urban and rural settings play a major role in enhancing the sustainability of agricultural systems. For wheat farming in Syria, production doubled in two decades due

to development of improved germplasm and management practices by ICARDA; future gains will likely depend on other adaptations such as legume/cereal rotations. In the North Central USA, net returns from a 4-year organic crop rotation, with and without organic premiums, were greater than or equal to those of a corn-soybean rotation using synthetic pesticides or chemically processed fertilizers. As reported by Kratochhvil in Austria, organic farming not only increases the availability of healthy, high-quality food, but results in preservation of natural resources and overall food security. Advantages to agricultural and social sustainability, due to the empowerment of women, is demonstrated by the adoption of alley farming with leguminous trees in Nigeria that increased agricultural production and the quality of life of women farmer adopters. In his book *Ecocide*, Brosnimmer suggests that the structure of society might be altered to reduce our impact on other species.

The changes in the journal are intended to advance the goal of creating a common ground where scientists, educators, policymakers, farmers, and other practitioners of various perspectives and viewpoints can share their research and ideas. This is highlighted by Kamyar Enshayan's Forum article on 'Local Food, Local Security' that advocates the benefits of locally produced food on safety and security. The divergence of opinion about what constitutes a 'safe' food supply is well illustrated by the thoughtful, yet differing, responses of Wally Wilhelm and Kate Clancy on this issue. The Editorial Board looks forward to the journal serving as a forum where conventional agriculturalists, striving toward more sustainable systems, can interact with others in organic, biological, and biointensive agriculture to develop an agriculture that will achieve the vision of "Sustaining Earth and Its People."

John W. Doran
Editor-in-Chief

Local food, local security

Kamyar Enshayan

Forum

There is much talk about homeland security, bioterrorism and how to safeguard our system of food and agriculture from terrorists. But if we look around us, we see that the forces systematically destroying American agriculture are almost entirely domestic: nitrogen pollution of our streams, atrazine in our drinking water, farm policies that kill independent businesses and small towns, genetic manipulation for profits and power, and monopolization of agricultural markets by a few global corporations.

One clear and troubling example of a domestic biological threat to our system of food and agriculture is the way the industrial meat giants raise and process livestock. In 2002, roughly during the same time that snipers killed 12 people around the nation's capital, contaminated lunch meat killed more than 8 people and sickened many more in New England, prompting a record recall of 27 million pounds of meat. I asked my students what differences there were between the two tragedies. The class had just read Eric Schlosser's *Fast Food Nation*, which documents how packing giants repeatedly evade public health laws, leading to meat contamination and death. The only differences my class saw were that the shootings received massive news coverage but the poisoning victims died quietly in hospitals with little media attention, and while there was an extensive search for the snipers, there were no arrests in the meat industry.

There are other ways of protecting our food and agriculture. My friend Mary Berry Smith, who farms in Kentucky, says 'Our country, through its ruinous desire for cheap food, has nearly destroyed the safest food system we could have: farmers feeding the people closest to them.' Her family sells most of their farm products direct to customers: 'Our customers trust us to provide delicious, healthy, safe food; we trust them to pay us a fair price.'

The people of Black Hawk County, Iowa, annually spend nearly US\$240 million on groceries and another US\$130 million on eating out. Most of these food dollars leave our county and state. Six years ago, I approached the dining services directors of our university, our local hospital and the owner of a locally owned restaurant about buying a greater portion of their food from nearby farms. The aim was to keep a significant part of these dollars in our community and region, as well as to build local relationships. 'Value-subtracting' industrial agriculture and the resulting 'value-missing' markets create insecurities for the very people who grow our food.

Ten institutions we have worked with over 5 years have spent nearly US\$780,000 of their food purchases locally. At Rudy's Tacos, one of our partners in Waterloo, 71% of the restaurant's food budget, US\$143,000, goes for fresh, locally grown ingredients. For most restaurants, that percentage would be in single digits, if any. Bartels Lutheran Home in Waverly, another partner, buys two to three cattle each month, raised locally and processed at a local meat locker. Last year Bartels bought US\$40,000 worth of locally raised beef and vegetables. Three years ago the beef came from an unknown source, and the US\$40,000 left the region. The University of Northern Iowa, where I work, recently bought its first local cow!

This is 'value-retained' agriculture, and we need more of it. If our county set a goal of retaining just 10% of our food dollars, that would amount to US\$37 million *every year*. And that would be real community economic development based on our best assets: our people and our land.

These institutional food buyers have come to understand that their decisions affect crucially the vitality of nearby farms and businesses. They have decided to buy their meats from farmers they know for this reason, and because they can find out what the animals were fed and how they were raised. Through local, inspected lockers they are assured that their ground beef came from *that* cow, and not from a mixture of thousands of other cattle from unknown places. Obviously, local meat lockers can also be susceptible to meat contamination and must follow strict meat safety guidelines. The key is local accountability and traceability to a farm, to a specific feed, etc.

This work has expanded the web of local relationships, which is the essence of local economy and local life. This is the kind of homeland security I think about.

Kamyar Enshayan works at University of Northern Iowa, Cedar Falls, Iowa. Many thanks to the Leopold Center for Sustainable Agriculture and NCSARE for supporting the institutional marketing project. The original commentary, entitled 'Food Security Begins and Stays at Home', was presented at the Land Institute Prairie Festival in September 2002 and was printed in 'The Land Report' Number 75, Spring 2003, pages 8–9. For a summary of 5 years of work with institutional food buyers in north-eastern Iowa, please visit <http://www.uni.edu/ceef/food-project>

Editorial response by Wallace Wilhelm

Dr. Enshayan expresses good ideas and views that are appropriate during this time of international uneasiness. I respect Dr. Enshayan for having the courage to express his position openly and for making me think deeply enough about the topic to realize I have a somewhat different opinion. Our different points of view may span the range of opinions held by the readers of RAFS. In that regard, Dr. Enshayan may have also established a forum for a valuable discussion among our readers.

I compliment Dr. Enshayan for opening the issue of local production and consumption of agricultural products. He raises several extremely important points: increasing enterprise income by locally adding value to agricultural products; adding to the sense of community by buying from and selling to neighbors; and maintaining a fraction of local control over our food supply (quantity, quality, safety and healthfulness) through local buying and selling. However, I think he has missed two important points in this discussion. First, most people in the US assume our food supply is safe and healthful. This assumption is the result of decades of control by a series of US government regulations that have elevated the standards for food handling and processing to a point where food can be assumed to be safe (US Food and Drug Administration, 2000, <http://www.fsis.usda.gov/OA/codex/system.htm>). Food, regardless of source, is neither safe nor hazardous. The standards during production, processing, transport and storage largely impart the characteristics of safety and healthfulness (Woteki et al., 2001, <http://www.nutrition.org/cgi/content/full/131/2/502S>). Food-related illnesses (poisonings) are unusual events and therefore draw media attention. If they were an everyday event, print and broadcast media would not highlight them; they sell newspapers and capture market share by highlighting the unusual and tragic, not restating everyday events. Secondly, some improvements in public health can be attributed, in part, to having a wide array of

foods available to everyone at a relatively low cost. Nutrition-related diseases are as uncommon today in the US as food poisoning. Having an effective food production, processing, storage and marketing industry capable of delivering exotic fruits, vegetables and other produce safely, and at a low cost, has benefited all in our society. The most revealing statement one can make may be the fact that the greatest concern, and the most-repeated story relating to public health and food-related diseases, is overweight and obesity. If we relied solely on locally produced food, our food supply would differ greatly from that to which we are accustomed. We would have an abundance of food during the summer and fall months, if local weather condition were favorable, but we would have to process and store some of this abundance for consumption during the winter and spring when fresh produce is not available. This situation is not greatly different from the food supply scenario that existed in the first half of the 20th century. Our food production industry has evolved since that time, maybe not entirely for the better, but it has changed.

We now have great metropolitan areas with massive populations. People in these cities rely on the existence of an efficient food production and distribution system. I am reasonably sure Dr. Enshayan was not suggesting complete abandonment of our food industry infrastructure. At best that would be an intricate, hazardous process. However, in individual cases, where the opportunities exist, there can be benefit to both buyer and seller to seek, and profit from, local markets.

Wallace Wilhelm is Resource Review Editor for RAFS and a Plant Physiologist with the USDA, Agricultural Research Service in the Soil and Water Conservation Unit at the University of Nebraska, Lincoln, NE 68583 (wwilhelm1@unl.edu).

Kate Clancy's response to Forum and Editorial Comments

The commentaries by Enshayan and Wilhelm are a good example of a debate that has been going on for 25 years or so in the US. One of the major questions in this debate is what percentage of the food system can be occupied by local/regional alternatives and what percentage will remain in the dominant, industrial system. Although I disagree strongly that food-related illnesses are unusual (USDA data show an epidemic of such disease) and that most nutrition-related diseases are uncommon (the three leading causes of death in the US are diet-related), I believe it will be many

years before a majority of consumers take the extra time and money to buy local and sustainably produced food. Therefore, we will continue to work on developing the alternative and trying to reform the dominant for some time to come.

Kate Clancy is director of the Wallace Center for Agricultural and Environmental Policy and serves as senior manager for Winrock International's domestic agricultural programs.

Pesticide Free Production: Characteristics of farms and farmers participating in a pesticide use reduction pilot project in Manitoba, Canada

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Research Paper

Abstract

Strategies for pesticide use reduction have suffered from limited adoption. The impact of such strategies will be greater if they appeal to farmers with typical demographics and attitudes. A participatory, on-farm study was conducted to assess the potential of Pesticide Free ProductionTM (PFP) to be widely implemented on mainstream farms in Manitoba, Canada. PFP is a flexible, simple framework intended to appeal broadly to farmers who may not have adopted other pesticide use reduction initiatives. It may also provide a marketable food product label. This novel crop production system prohibits the use of in-crop pesticides and seed treatments during one crop year, as well as prior use of residual pesticides. Applications of nonresidual pesticides (such as glyphosate) are permitted prior to crop emergence. Synthetic fertilizer use is permitted at any time. The objectives of this study were: (1) to determine if the demographic and attitudinal characteristics of farms and farmers participating in a PFP pilot project varied depending on the level of PFP implementation; and (2) to compare the characteristics of farms and farmers participating in the pilot project with standards representing average farms and farmers in Manitoba. A total of 71 farmers, representing 120 fields and 11 crops, participated in the study. Fields and farmers were categorized into three groups, based on whether or not fields: (1) achieved PFP certification status and (2) were in transition to organic production. There were few demographic differences among groups. Demographic characteristics of participating farmers were typical for Manitoba, with the exception that participating farmers who were not in transition to organic production had higher levels of education than a random sample of Manitoba farmers. Attitudinal orientation (adherence to a conventional versus an alternative agricultural paradigm) of participants who were not in transition to organic production was similar to that of a random sample of Manitoba farmers. Fields and farms on which PFP was implemented were relatively large in the context of Manitoba averages. Participants indicated high satisfaction with certifiable PFP crops and high levels of interest in implementing future PFP. Pesticide free production demonstrates significant potential for broad adoption in this region.

Key words: Pesticide Free Production, PFP, integrated pest management, IPM, participatory research, pesticide use reduction, low-input agriculture, Manitoba, Alternative–Conventional Agriculture Paradigm scale, ACAP scale, flax, spring wheat, barley, oats

Introduction

Pesticide use reduction has received considerable attention as a means to mitigate negative environmental impacts, reduce production costs, and meet demand for specialized markets. While various strategies for pesticide use reduc-

tion exist, their adoption in the North American Northern Great Plains (NGP) has been limited. In the province of Manitoba, Canada, organic crop production comprises less than 0.5% of the province's total field crop area [unpublished data, Organic Producers' Association of Manitoba (OPAM)]. Frameworks for pesticide use reduction with more flexibility than organic production have been developed (e.g. integrated pest management, IPM), but have not been widely implemented^{1,2}. Despite this, a large proportion of farmers may be amenable to imple-

Pesticide Free ProductionTM and PFPTM are registered trademarks of the University of Manitoba.

menting approaches to achieve some degree of pesticide use reduction^{3,4}.

In order to capture mainstream farmers' interest in pesticide use reduction, a team of farmers, researchers and extension workers in Manitoba developed Pesticide Free ProductionTM (PFP) in 1999. Representatives from the University of Manitoba, Agriculture and Agri-Food Canada in Brandon, Manitoba, and Manitoba Agriculture and Food were involved. PFP is a flexible, simple framework intended to appeal broadly to farmers who may not have adopted other pesticide use reduction initiatives. PFP crops are defined as nongenetically modified crops that are not treated with pesticides after the crop emerges, and are not grown where residual pesticides are considered to be agronomically active⁵. These guidelines prohibit the use of in-crop pesticides and pesticidal seed treatments for one crop year. Prior use of pesticides is permitted only if the product is considered not to have active residual at the time of PFP crop seeding, as indicated by the manufacturer's recropping restrictions. Synthetic fertilizer use is permitted at any time, and applications of nonresidual pesticides, such as glyphosate, are permitted prior to the emergence of the PFP crop. PFP may draw mainstream farmers to explore integrated approaches to pest and crop management. It may also provide a marketable food product label⁶.

According to classical technology adoption theory, technology adoption in agriculture is related to demographic characteristics of farmers, and occurs initially among young, well-educated farmers who operate relatively large farms, and own rather than rent land⁷. However, innovations that are primarily focused on environmental benefits ('environmental innovations', e.g., IPM) are fundamentally different from traditional technologies, in that they may be complex groupings of practices which are not necessarily applicable to all farms, and they may offer more benefit to society as a whole than they do to adopters⁸. The demographic and attitudinal characteristics important in the adoption of environmental innovations may be different than those for traditional technologies. Some studies have found demographic and attitudinal differences between farmers practicing conventional versus reduced-input agriculture^{9,10}. Others have found that farmers interested in reducing pesticide use are demographically and attitudinally similar to mainstream farmers^{3,4,11}. Farmer support for reduced-input practices has also been reported to be related more to attitudinal than demographic factors¹¹.

The potential impact of a given pesticide use reduction strategy will be greater if the strategy appeals to farmers with average or typical demographics and attitudes. The adoption of pesticide use reduction strategies can be facilitated through targeted extension if the target group of farmers and farms can be characterized.

The objective of this study was to assess the potential of Pesticide Free Production to be widely implemented on mainstream farms in Manitoba, Canada. We aimed to meet this objective by: (1) determining if the demographic and

attitudinal characteristics of farms and farmers participating in a PFP pilot project varied, depending on level of PFP implementation; and (2) comparing the characteristics of farms and farmers participating in the pilot project with standards representing average farms and farmers in Manitoba.

Materials and Methods

Participant and field selection

Farmer participation was an integral part of the project. Participatory research utilizes farmers' expertise and can promote rapid adoption of novel production systems¹². The specific requirements for PFP meant that participation was constrained by interest among Manitoba farmers, resulting in nonrandom, purposive sampling. Participants were recruited in the late winter of 2000 and 2001, via newspaper and radio advertisements, promotion by provincial agricultural representatives, and word of mouth among farmers. No compensation was offered, and participants were informed that there were no clear premium marketing opportunities for PFP-certified grain at the time the study was conducted. Farmers were selected to participate if their fields could meet PFP certification criteria. Several farmers volunteered more than one field.

During the first year of the project (2000), all volunteered grain crop fields were included. Fields in transition to organic certification were included. In 2001, there was sufficient interest in PFP that the study was narrowed to include only those crops showing high levels of farmer interest [spring wheat (*Triticum aestivum* L.), oats (*Avena sativa* L.), barley (*Hordeum vulgare* L.) and flax (*Linum usitatissimum* L.)].

Questionnaire design

Participants were asked to complete a detailed written questionnaire distributed by mail. Questionnaire design was in accordance with University of Manitoba ethical research requirements and based on guidelines provided by Sudman and Bradburn¹³, Jackson¹⁴ and Babbie¹⁵. The questionnaire was pretested on ten subjects with farming backgrounds, and modified where required. Unclear responses were clarified via telephone interviews. The questionnaire consisted of questions regarding farmers' agronomic practices, demographic information and feedback about PFP. In addition, a series of questions designed to determine farmers' adherence to an alternative or a conventional agricultural worldview was included [Alternative-Conventional Agriculture Paradigm scale (ACAP scale)]⁹. The reliability of this scale has been established by its repeated use in sociological research, in both the United States and Canada^{3,4,9,10,16,17}. The scale has been shown to be related to farmers' production practices^{16,17}. In our study, the only modification made to this series of questions was to change the term 'US agriculture' to 'North American agriculture'.

Another questionnaire was used to follow up with farmers who had produced certifiable PFP fields, conducted via telephone 1 year after harvest of the PFP crop. Open-ended questions were used to elicit responses about weed densities the year after PFP.

In order to gain information about the demographic and attitudinal characteristics of typical Manitoba farmers, a questionnaire was conducted by a professional polling company with significant agricultural experience (Ipsos-Reid Corporation, Winnipeg, MB) in February 2002. A stratified random sample of 154 farmers (each with over 130 ha of seeded cropland) was used, with proportions representing the population distribution in each Manitoba census district. A telephone survey was used to minimize self-selection of respondents. The margin of error was $\pm 8\%$ at the 95% level of confidence. The refusal rate was 30%, which is within the normal range for agricultural surveys conducted by Ipsos-Reid.

Data analysis

Fields and farmers were categorized into three groups, representing different levels of pesticide use reduction in the year PFP was attempted. Initially, fields were divided into two groups, based on whether or not the field met PFP certification requirements. Fields that met the requirements were further subdivided into two groups, based on whether or not the field was in transition to organic certification. The classification was based on the farmer's ability to meet PFP certification requirements rather than a determination of the 'successfulness' of a field in terms of pest pressure. The three groups of fields were as follows: (1) those not certifiable as PFP (*noncertifiable fields*); (2) those certifiable as PFP but not in transition to organic certification (*certifiable, nontransitional fields*); and (3) those certifiable as PFP and in transition to organic certification (*certifiable, transitional fields*). Farmers were categorized into three groups comparable to the field-based groupings: (1) those with no certifiable PFP fields (*farmers without certifiable fields*); (2) those with certifiable PFP fields whose farms were not in transition to organic (*farmers with certifiable fields, nontransitional farms*); and (3) those with certifiable PFP fields whose farms were in transition to organic (*farmers with certifiable fields, transitional farms*). When considered together, the noncertifiable and certifiable, nontransitional groups are referred to as the 'conventional' groups. It should be emphasized that the 'noncertifiable' designation does not necessarily imply typical Manitoba fields or farmers. For example, two fields in the noncertifiable group were in transition to organic but were not certifiable as PFP because a residual herbicide had been used previously.

The relatively small number of participants meant that separation of observations by year, soil type, or tillage system would have resulted in groups so small as to prohibit meaningful comparison. Observations were combined into one data set across both years, providing a broad

description of farmers and fields involved in PFP. Duplicate values were removed if farmers participated in both years.

Analysis of variance (ANOVA) was performed for comparisons of continuous numerical variables. Participant group was the only source of variation included in the model. Fisher's protected LSD was used to separate means. When data could not be transformed to meet normality, Mann-Whitney and Kruskal-Wallis tests were used. These are the non-parametric equivalents of two-sample *t*-tests and one-way ANOVA, respectively¹⁸. Pairwise comparisons using the Mann-Whitney test were carried out if the overall Kruskal-Wallis test was significant ($P < 0.05$). When the outcome of a nonparametric test agreed with the outcome of ANOVA ($P < 0.05$), the ANOVA result was presented. If data could be transformed to meet normality, but results agreed with the outcome of ANOVA on the untransformed data, the results for the untransformed data were presented. Contingency tables and chi-square statistics were generated for comparisons of frequencies of categorical data. If tables contained response variables that were not ordinal, Pearson's chi-square was used to test the null hypothesis of no general association. For tables with ordinal response categories, the Mantel-Haenszel chi-square was used to test for linear response¹⁸. When zero counts were generated in a table, or if more than 20% of table cells had an expected value of less than 5, Fisher's exact test was used¹⁸. Contingency tables were used to generate pairwise comparisons if the overall chi-square test was significant ($P < 0.05$).

Information describing typical Manitoba farms and farmers was obtained from government agencies, farmer surveys conducted by various organizations, and peer-reviewed publications. Comparative information for which there was no published source was obtained from appropriate industry representatives.

Results and Discussion

Participation

Less than 1% of annual cereal and oilseed fields in Manitoba are produced without a herbicide application¹⁹. Given this context, participation in the project was very good. A total of 71 farmers and 120 fields were included, of which the majority were located in western Manitoba (agroecoregion 2 of the Northern Great Plains)²⁰. This region produces fewer high-value crops and more forage crops than Manitoba's other major agroecoregion (agroecoregion 1), and also has a relatively high frequency of reduced-tillage¹⁹. Farmers volunteered 11 crops for the study, primarily cereals [spring and winter wheat, fall rye (*Secale cereale* L.), barley, and oats], as well as flax. In total, 2368 ha of the 2850 ha volunteered was PFP-certifiable, representing 83% of the land area and 68% of fields volunteered. The proportion of certifiable fields varied depending on the crop type. Detailed information

Table 1. Reasons for farmer interest in Pesticide Free Production (PFP).

Farmer group	Input cost reduction	Marketing opportunities	Health concerns	Prevention of pesticide resistance	Environmental concerns
----- Average score ¹ -----					
Without certifiable PFP fields	4.7 (0.13) ²	4.5 (0.22)a	3.9 (0.32)a	4.1 (0.30)	3.5 (0.29)
With certifiable fields, nontransitional farms	4.6 (0.14)	3.1 (0.23)b	4.0 (0.19)a	3.5 (0.21)	4.0 (0.18)
With certifiable fields, transitional farms	4.6 (0.21)	4.1 (0.19)ab	4.6 (0.18)b	4.0 (0.24)	4.3 (0.19)
<i>P</i> value	0.89	>0.001	0.03	0.23	0.11
<i>n</i>	66	64	66	65	65

a, b Means followed by the same letter within columns are not significantly different ($P > 0.05$) according to Fisher's protected LSD.

¹ Scores range from 1 to 5, with 5 indicating high interest.

² Numbers in parentheses represent standard errors.

regarding farmer participation and agronomic characteristics of participating farms is reported elsewhere²¹.

Participant interest in reduced-input agriculture

Reasons for participant interest in PFP. Economic considerations are often very important in the adoption of conservation or reduced-input practices²², and our results demonstrate that the same is true of PFP implementation. The highest-ranking reason for interest in PFP among all groups was input cost reduction, and there were no significant differences in scores for this factor (Table 1). This can be attributed to the current financial difficulties for grain farmers in western Canada. Input cost is one factor over which farmers can maintain some control²³. There was significantly higher interest in marketing opportunities among farmers without certifiable fields than among farmers with certifiable fields, nontransitional farms. This suggests that farmers who did not retain fields for certifiable PFP did so partly because of the lack of premium marketing opportunities for PFP grain at that point in time, and that this group may be more likely to implement PFP if such opportunities were available.

Noneconomic factors can also be important in farmers' decisions to reduce agrichemical use²⁴. This was true of all groups of PFP participants, who rated their interest in PFP for three different noneconomic reasons as above 3.5 on a 5-point scale (Table 1). Interest in PFP because of concern for their own or their families' health was significantly higher for farmers with certifiable fields, transitional farms than for farmers in either of the other two groups. Several participants stated that their health had been negatively impacted by exposure to pesticides. There were no significant differences among groups in the level of interest in PFP because of concern about the environment, or because it could reduce the risk of pesticide resistance. Others have reported that concern about environmental pollution is consistently positively correlated with farmer willingness to adopt pesticide use reduction practices¹¹; however, economic factors often take precedence over such concerns²⁵.

Participant interest in organic production. Several participants were farming organically but were not certified, citing certification costs and marketing difficulties as disincentives to certification. Some farmers were interested in alternating between organic and conventional production on a given field, but could not obtain organic certification for such fields. Others were using synthetic fertilizer but no pesticides on a long-term basis. PFP became a label for reduced-pesticide practices that these farmers were already implementing. Farmers in transition to organic production were interested in PFP as a market for transitional crops. In this dryland region, soil erosion and water conservation are important considerations, leading some farmers to state that the combination of zero-tillage and regular PFP may be more sustainable than organic production that relies more heavily on tillage for weed control.

Only 44% of the 25 participants who were in transition to organic planned to convert their entire farm to organic, even though this is required by many certification agencies²⁴ (data not shown). PFP may provide an alternative for farmers who are interested in organic production but prefer not to convert their entire farm.

Field selection for PFP attempts

From a list of options, farmers were asked to choose their reasons for attempting PFP on the given field. All certifiable, transitional fields were selected for PFP because of their transitional status. Among the other two groups, there were differences with respect to the distribution of reasons for field selection. Nineteen percent of certifiable, nontransitional fields were selected for PFP 'by default'; meaning that the window for herbicide application was missed or that the field was underseeded to a forage species that did not permit herbicide application. Selection of fields for PFP on the basis of advance preparation for reduced-input crop production was the most common reason given for both noncertifiable fields (63%) and certifiable, nontransitional fields (71%). A lower proportion of fields in both groups was selected without the farmer indicating

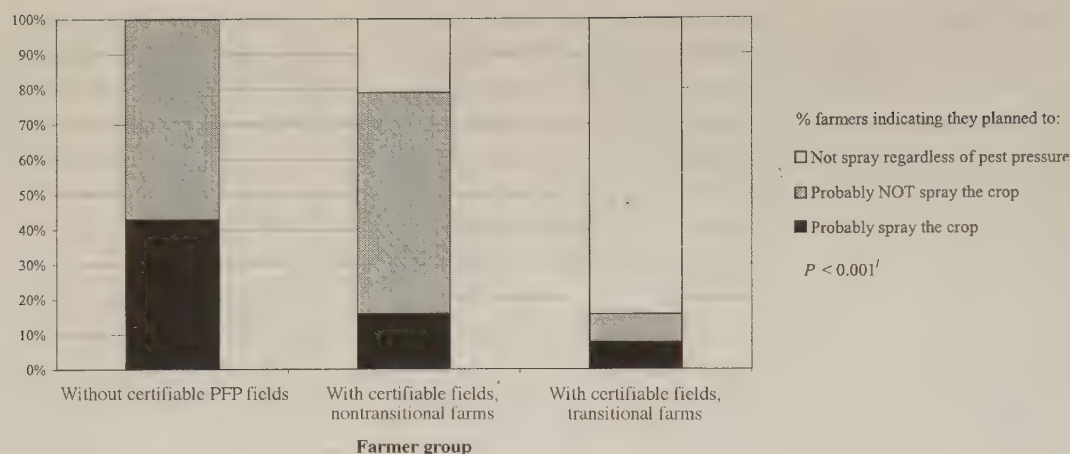


Figure 1. Farmers' approach to Pesticide Free Production (PFP) during early-season crop development ($n=32$; question asked in 2001 only). ¹Analysis was based on differences in distribution of approaches, rather than proportion of responses for each approach.

any advance preparation for reduced inputs, with 25% of noncertifiable fields and 11% of certifiable, transitional fields selected for this reason.

Farmer commitment to PFP during early-season crop development

During the initial stages of the project, the level of commitment towards implementing PFP was significantly different among groups ($P<0.001$) (Fig. 1). Compared to farmers with certifiable fields, a relatively large proportion of farmers without certifiable fields indicated that their PFP attempt would likely not be successful because they probably would apply pesticide to the field. Similarly, a larger proportion of farmers with certifiable fields indicated that they planned not to spray the field regardless of the level of pest or weed infestation, as compared to farmers without certifiable fields. Results suggest that farmers with certifiable fields had a somewhat higher level of commitment to achieving PFP certification than farmers without certifiable fields.

Demographic characteristics of participants

Age and number of years of farming experience. Age group was not significantly different among project participants, nor between participants and the random sample of Manitoba farmers (Table 2). As a comparison, 67% of Manitoba farmers were under 55 in 2001²⁶. The average number of years of farming experience was also not significantly different among groups (Table 2). While younger, less experienced farmers are expected to be more environmentally aware and more likely to adopt sustainable practices²³, there is no consensus regarding the relationship between farmers' age and environmental concern¹¹.

Farm income and off-farm employment. There were no significant differences in net farm income categories among groups (Table 2). While higher income is often associated with early adoption of traditional technologies²⁷,

farmers' income and environmental concern are generally not significantly related¹¹. Net farm income of project participants was not significantly different from that found in the random sample of Manitoba farmers. The average net farm income in Manitoba in 2001 was \$21,815 (Canadian dollars)²⁸.

There were no significant differences in the level of off-farm employment among groups (Table 2). However, off-farm employment in all groups was less than the Manitoba average (46% in 2001)²⁶. There is no consensus regarding the relationship between off-farm income and pesticide use reduction¹¹. Farmers with off-farm employment may find it less risky to experiment with pesticide use reduction because they have an alternative income. On the other hand, farmers without off-farm employment might have time to manage their systems intensively in order to achieve pesticide use reduction.

Educational level. Farmers with certifiable fields, transitional farms and farmers without certifiable fields had significantly higher proportions of post-secondary education than the random sample of Manitoba farmers ($P=0.03$) (Table 2). Classical technology adoption theory predicts that farmers with more education will be more likely to adopt new innovations²⁷. It would therefore be expected that farmers with higher levels of education would be more likely to implement pesticide use reduction. However, there was a decreasing proportion of participants with post-secondary education among groups with greater reductions in pesticide use ($P=0.10$) (Table 2). This lends some support to criticism of the classical technology adoption theory on the grounds that it does not adequately describe the adoption of nontraditional, environmental innovations. Despite this, results do indicate that the majority of project participants had higher than average levels of education. Most comparisons between conventional and organic farmers do not show significant differences in level of formal education^{11,25}.

Field and farm size. Field sizes for all participant

groups ranged from 3 to 130 ha. Average field sizes were not significantly different among participant groups ($P=0.065$) (Table 3). However, certifiable, nontransitional fields tended to be smaller than certifiable, transitional fields. It appears that farmers who were not in transition to organic production were more likely to implement pesticide use reduction on smaller fields, which is consistent with classical technology adoption theory regarding the initial stages of adoption²⁷. However, average field sizes for all participant groups were larger than the 21 ha average field size for annual crops in Manitoba¹⁹, and larger than the average field size on organic farms in the NGP (17.6 ha)²⁹. This indicates that fields on which PFP was implemented were relatively large in the context of typical Manitoba farms, and suggests that participating farmers were willing to experiment with pesticide use reduction on a relatively large scale.

Farmers operating smaller farms may be more likely to adopt sustainable practices^{16,23}. However, the role of farm size in the adoption of sustainable farming practices has been inconsistent in most comparative studies²⁵. Average farm size was not significantly different among participant groups, nor between the three participants groups and the random sample of Manitoba farmers (Table 3). Average farm size for all participant groups was larger than the Manitoba average of 361 ha in 2001²⁸. Our results suggest that PFP is of interest to farmers operating relatively large farms.

Number of people involved in farm operation. The number of people involved in the farm operation was not significantly different among groups, nor was the land area farmed per farm operator (Table 3).

Land tenure. The proportion of rented fields was not significantly different among groups (Table 3). There were no significant differences among groups in terms of the proportion of farm land that was rented (Table 3). There is conflicting evidence over the role of land ownership in the adoption of sustainable farming practices⁸. Tenancy (rather than ownership) has been found to be negatively related to the adoption of sustainable practices¹⁶. However, economic pressures may override incentives for conservation associated with land ownership³⁰.

Production of livestock. The integration of livestock into the farm operation can increase the use of forages and allow for herbicide use reduction³¹. In the present study, the proportion of farms producing livestock (primarily beef cattle) was not significantly different among participant groups and the random sample of Manitoba farmers (Table 3). Values were similar to those reported by Statistics Canada²⁸.

Production of pedigreed seed. There were no significant differences in the proportion of pedigreed seed growers in each group (Table 3). In 2002, 680 farms in Manitoba produced certified seed (Iris Yuill, Manitoba Seed Growers Association, personal communication), representing 3.6% of Manitoba farms. Pedigreed seed

Table 2. Demographic and attitudinal characteristics of farmers attempting to produce Pesticide Free Production (PFP) crops.

Group	Mean years farming experience	Age 55 or less	Net farm income >US\$25,000	Off-farm work	Post- secondary education	Previous PFP crop	Mean ACAP score ¹
----- % -----							
On-farm study participant groups							
Without certifiable PFP fields	27.3 (2.83) ²	61.5	83.3	20.0	76.9a	25.0a	88.0 (3.85)a
With certifiable fields, nontransitional farms	22.6 (1.15)	88.9	52.0	39.3	65.4a	53.6a	92.2 (1.79)ab
With certifiable fields, transitional farms	26.9 (1.86)	72.7	66.7	39.1	50.0ab	66.7b	97.9 (2.55)b
Random sample of Manitoba farmers ³		74.7	72.6	–	43.4b	–	88.9 (1.05)a
<i>P</i> value for PFP	0.11	0.12	0.61	0.29	0.10	0.02	0.046
participant group effect							
<i>P</i> value for random sample versus PFP groups	–	0.25	0.15	–	0.033	–	0.011
<i>n</i> ⁴	65	62	58	66	61	65	61

a, b Means followed by the same letter within columns are not significantly different ($P>0.05$) according to Fisher's protected LSD.

¹ Primary operator's score for Alternative–Conventional Agricultural Paradigm scale (ACAP); scores range from 24 to 120, with lower scores indicating adherence to a conventional paradigm⁹.

² Numbers in parentheses represent standard errors. Standard errors are not reported for percentage values that represent yes/no responses.

³ Random sample of 154 Manitoba farmers conducted by Ipsos Reid Corp. (Winnipeg, MB).

⁴ Number of observations within PFP groups only.

Table 3. Demographic characteristics of farms on which Pesticide Free Production (PFP) was attempted.

Farmer group	Mean farm size	Mean field size	Mean no. farm operators	Mean ha per operator	Mean rented land per farm	Project field rented	Pedigreed seed farms	Livestock farms
	----- ha -----					----- % -----		
On-farm study participant groups								
Without certifiable PFP fields	669 (98.5) ¹	31.3 (4.29)	2.6 (0.40)	283 (40.8)	17.6 (4.51)	5.6	20.0	46.7
With certifiable fields, nontransitional farms	655 (87.8)	25.5 (2.30)	2.6 (0.20)	271 (32.4)	25.3 (4.18)	14.8	21.4	42.9
With certifiable fields, transitional farms	528 (79.0)	38.6 (6.09)	2.1 (0.19)	235 (33.6)	24.4 (5.67)	18.8	34.8	43.5
Random sample of Manitoba farmers ²	495 (34.1)	—	—	—	—	—	—	37.7
<i>P</i> value for PFP participant group effect	0.51	0.065	0.19	0.65	0.55	0.40	0.26	0.87
<i>P</i> value for random sample versus PFP groups	0.16	—	—	—	—	—	—	0.84
<i>n</i> ³	66	120	66	66	66	114	66	66

¹ Numbers in parentheses represent standard errors. Standard errors are not reported for percentage values that represent yes/no responses.

² Random sample of 154 Manitoba farmers conducted by Ipsos Reid Corp. (Winnipeg, MB).

³ Number of observations within PFP groups only.

growers are highly represented in all PFP participant groups. Seed growers may be more likely to have the intensive crop management skills required to implement pesticide use reduction. They also tend to have increased access to grain-cleaning facilities to reduce the impact of weed seeds that are separable from grain. However, contamination tolerances for weeds in seed crops are very low, and seed growers may be concerned about weed densities in fields intended for seed production subsequent to PFP. Some participants did select fields for PFP that were intended for seed production, and stated that they terminated PFP attempts only because of the potential impact of weeds on the certification of the seed crop.

Affiliations with agricultural organizations. Membership in different types of farm organizations may be representative of, or may influence, farmers' perceptions of acceptable farming practices and knowledge of sustainable practices^{10,22}. There were, however, no significant differences in organizational affiliation among groups in this study (Table 4).

Agricultural paradigm scores

There were significant differences in average Alternative–Conventional Agricultural Paradigm (ACAP) scale scores among participant groups (Table 2). Farmers without certifiable fields had a significantly lower average ACAP score than farmers with certifiable fields, transitional farms. This indicates adherence to a more conventional paradigm among farmers without certifiable fields. Farmers with

certifiable fields, nontransitional farms had an average ACAP score intermediate to, but not significantly different from, both other groups. The average ACAP score of the random sample of Manitoba farmers was not significantly different from either of the 'conventional' groups of participants, but was significantly lower than the average score of farmers with certifiable fields, transitional farms (Table 2). This indicates that participating farmers who were not in transition to organic had attitude scores typical of Manitoba farmers. Beus and Dunlap⁹ found that members of known alternative agriculture groups had average scores of 90 or over on this scale, while a random sample of farmers in Washington State had an average score of 80.9. Allen and Bernhardt¹⁶ found that farmers using alternative production practices scored over 89, while those using conventional production practices scored below 80. In our study, average scores for all PFP participant groups and the random sample of Manitoba farmers were over 88, suggesting that paradigmatic orientations of North American farmers may be shifting toward the alternative paradigm, or that attitudes vary by region. Our findings support previous work indicating that farmer paradigmatic orientation is related to production practices¹⁷, in terms of farmer adoption of organic production.

Farmers' perceptions related to PFP

Perception of PFP as an acceptable practice. The proportion of farmers stating that they thought PFP was a practice acceptable to most farmers was not significantly

Table 4. Affiliation of farmers attempting Pesticide Free Production (PFP) with agricultural organizations ($n = 66$).¹

Farmer group	Agricultural organization				
	Sustainable ²	General	Commodity ³	Other ⁴	None
	----- % farmers -----				
Without certifiable PFP fields	12.5	56.3	37.5	6.3	31.3
With certifiable fields, nontransitional farms	29.6	33.3	14.8	7.4	21.9
With certifiable fields, transitional farms	30.4	34.8	43.5	0.0	30.4
<i>P</i> value	0.38	0.28	0.07	0.46	0.91

¹ Farmers could belong to more than one group.² Organic producer groups, zero-tillage groups, National Farmers' Union, or sustainable agriculture societies.³ For example, canola, cattle or seed producers' associations.⁴ Other, nonagricultural, rural community groups, e.g., municipal drainage committee.**Table 5.** Farmers' perceptions of Pesticide Free Production (PFP) and weed densities.

Farmer group	PFP was financially beneficial	Expect to increase future pesticide use ¹	PFP is acceptable to the majority of farmers	More tolerant to weeds than most farmers
	----- % -----			
Without certifiable PFP fields	—	—	30.8	28.6
With certifiable fields, nontransitional farms	90.3	6.0	35.7	30.0
With certifiable fields, transitional farms	90.9	0.0	40.9	54.6
<i>P</i> value	1.00 ²	1.00 ²	0.54	0.36 ²
<i>n</i>	53	30 ³	63	38 ³

¹ On the certifiable PFP field, as a result of having grown a PFP crop.² Fisher's exact test was used due to small sample size.³ Small sample size because question asked of producers only in 2001.

different among groups (Table 5). The perception that a practice is accepted by the farming community is important in its adoption⁸, and may influence adoption more than farm demographic characteristics¹¹. About one-third of farmers in all groups stated that they consider PFP to be a generally acceptable practice.

Perception of the financial outcome of PFP. Over 90% of farmers with certifiable fields stated that PFP was at least as profitable as producing a conventional crop (Table 5). Because premium markets for PFP grain were not yet established when this study was conducted, all farmers indicated that financial benefits were due to reductions in input costs. Many farmers indicated that the profitability of PFP was due to their management and selectivity in choosing fields for PFP. Other studies have demonstrated that production of crops without in-crop herbicide can result in similar average gross returns when compared to crops receiving herbicide³². Farmers' perceptions of the economic outcome of reduced pesticide use are critical to its adoption¹¹. Positive perceptions of the financial viability

of PFP support its potential for adoption.

Tolerance to weed densities. The proportion of farmers stating that they were more tolerant to weed pressure (than they would expect other farmers to be) was not significantly different among groups (Table 5).

Satisfaction with certifiable PFP. Farmers with certifiable fields were asked to rate their satisfaction with producing a PFP crop as good, fair or poor. Differences between the two certifiable groups were significant ($P=0.04$). Satisfaction was relatively low for certifiable, transitional fields (50% good, 36% fair, 14% poor), but higher for certifiable, nontransitional fields (74% good, 19% fair, 8% poor). Ninety-eight percent of farmers with certifiable fields surveyed 1 year after harvest indicated that they had no regrets about producing a PFP crop. This may reflect farmers' choice of suitable fields and their level of commitment to PFP. The need for good decision-making regarding field selection was frequently mentioned by participants as a requirement for successful pesticide use reduction.

Previous experience with reduced pesticide crop production

There were significant differences in the proportion of farmers in each group who stated they had grown a crop without in-crop pesticide prior to attempting a PFP crop as part of this project (Table 2) ($P=0.02$). Farmers with certifiable fields, transitional farms had significantly more experience with pesticide-free crops compared to the other groups. Other differences were not significant.

Future pesticide use intentions

Very few farmers stated that they thought they would have to increase their future pesticide use as a consequence of producing a certifiable PFP crop, and there were no significant differences among groups (Table 5). The majority of farmers also indicated that weed densities were manageable with their regular herbicide regime the year after PFP (data not shown). This supports the idea that PFP can allow for an overall reduction in pesticide use in a long-term cropping system.

Future intentions to produce PFP crops

Interest in future implementation of PFP was focused on spring and winter cereals; however, farmers suggested virtually every major crop in this region for future PFP attempts. There were no significant differences among groups in the proportion of farmers indicating that they would be interested in implementing PFP regularly depending on the availability of a marketing premium (Fig. 2). However, the level of interest in future PFP was lowest among farmers without certifiable fields.

When asked how long they would wait until attempting PFP on a field on which they had previously attempted PFP, farmers without certifiable fields were most likely to be unsure (75%) (data not shown). The majority of farmers

with certifiable fields, transitional farms were planning to implement PFP the following year as part of their transition to organic production. More than half of farmers with certifiable fields, nontransitional farms indicated that they would try PFP on the same field within 3 years, but only 13% indicated that they would attempt it on the same field 2 years in a row. Eighty percent of participants with certifiable fields intended to attempt PFP on some part of their farm the year following project participation (data not shown).

Several farmers suggested that their implementation of PFP in the future would depend on their crop rotation as well as premium marketing opportunities. A number of farmers indicated that they did not plan to alter their current management to achieve PFP, but would only implement PFP opportunistically on fields that happened to have low weed densities. Other participants suggested that they were trying to reduce their agrichemical input use regardless of whether or not they met PFP guidelines, but were still interested in being part of a group of farmers interested in pesticide use reduction.

Participants cited a number of barriers to PFP adoption. The availability of a marketing premium as an incentive was most commonly cited, followed by high weed densities requiring herbicide application. Other, less commonly cited, barriers included restrictions regarding use of residual herbicides; overcoming farmers' expectations of weed-free fields resulting from herbicide application; achieving identity-preserved separation of PFP grain; weed seed production in the absence of herbicides; management skills required for PFP; and lower crop yields.

Marketing premiums required by participants

Participants were asked what marketing premium they would require for regular implementation of PFP. Data for 2001 only were used, because of the lack of response to an

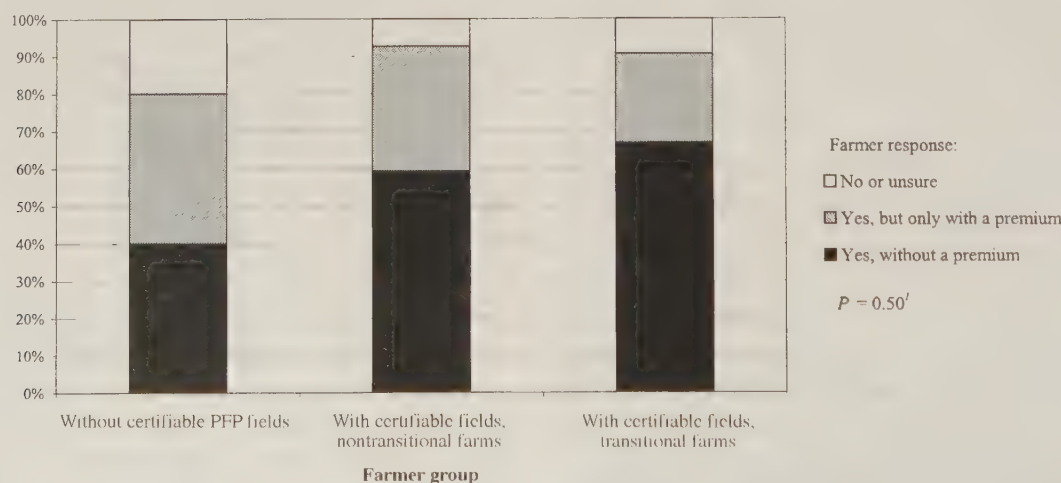


Figure 2. Response of farmers to the question 'Would you try Pesticide Free Production (PFP) in a regular crop rotation?' ($n=63$).
¹Analysis was based on differences in distribution of responses, rather than differences in proportion of responses for individual categories.

open-ended question in 2000. Farmers suggested that price premiums in the range of 20% above conventional grain prices for wheat, oats, barley and flax would be required, and farmers with certifiable fields, nontransitional farms tended to suggest the lowest premiums (data not shown). The suggestion of relatively high premiums by farmers without certifiable fields may be an indication of their high level of interest in marketing as a reason for PFP, while those with certifiable fields, nontransitional farms may require less compensation because of high interest in PFP for other reasons (Table 1). For farmers with certifiable fields, transitional farms, the requirement for premiums may reflect the expectations of high premiums for organic production. A recent survey regarding consumer interest in PFP food products indicated that there is a high probability that Canadian consumers are willing to pay low to moderate premiums for PFP food products at the retail level⁶.

Summary and Conclusions

Demographic characteristics of participants were generally similar regardless of their level of success with PFP. This suggests that demographic characteristics did not strongly influence participants' success in implementing PFP. Participants with certifiable fields, transitional farms had a significantly higher average ACAP scale score compared to those without certifiable fields, indicating stronger adherence to an alternative agricultural paradigm. However, the average ACAP score of participants with certifiable fields, nontransitional farms was not significantly different from other groups. This suggests that farmer attitudes may be more important for the adoption of organic production than for the implementation of PFP.

There were also few differences between participants and their farms and average farmers and farms in Manitoba. One exception was that PFP project participants who were not in transition to organic production had higher levels of education than is typical of Manitoba farmers. The paradigmatic orientation of farmers interested in PFP, who were not in transition to organic production, was similar to that of a random sample of Manitoba farmers. Fields and farms on which PFP was implemented were relatively large in the context of Manitoba averages. Our findings indicate that farmers who were interested in, and successfully implementing, PFP independently of a transition to organic production can be considered to be typical farmers for this region. Pesticide Free Production therefore shows good potential to be broadly adopted in this region. If farmers implemented PFP once every 4 years on one-third to one-half of their farms, land treated with pesticide would be reduced by approximately 8–12%. Our results also suggest that the development of this pesticide use reduction approach (PFP) could be facilitated via mainstream rather than marginal extension channels.

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The economic opportunities for increasing the use of forage legumes in north European livestock systems under both conventional and organic management

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Abstract

Changing from a conventional livestock production system, based on fertilized grass swards, to an organic management system requires the establishment of legume-based swards to replace the purchased fertilizer nitrogen. This paper reviews experimental-based research on both the comparative economics of legume-based systems and grass swards and also the economic advantage that forage legumes confer on organic systems. A methodology to determine the production costs and economic values of a variety of forage legume systems is outlined. The resultant methodology is then applied to experimental results from trials, conducted at a wide range of sites in northern Europe, to determine the comparative profitability of different legume-based systems of silage production under conventional management. The results indicate that potentially red clover (*Trifolium pratense* L.), and to a lesser extent white clover (*Trifolium repens* L.), and lucerne (alfalfa) (*Medicago sativa* L.), can produce higher profits per hectare than grass-based systems using high levels of nitrogen fertilizer. Galega (*Galega orientalis* Lam) and lotus (*Lotus corniculatus* L.) can, in certain circumstances, be economically competitive with fertilized grass swards, but would generally not be the forage legumes of first choice. From an economic standpoint, forage legumes are probably best grown in a mixture with grass. As some of the experimental sites involved organic treatments, the analysis has been extended to include an assessment of the comparative economics of organic systems of production based on forage legumes, relative to conventional grass-based systems. Thus, the third part of the paper is concerned with quantifying the economic advantage to organic systems conferred by forage legumes. The results indicate that, under careful management, their use for silage can produce higher profits per hectare for organic dairy systems than those obtained from conventional grass-based systems. While the relative performance of organic systems is strongly influenced by the price premium paid for organic milk, which has declined in recent years, not all the projected economic advantage of legume-based organic dairy systems is eroded by this trend. However, economic advantage is not enough to secure the widespread adoption of forage legumes. This will depend on technological developments and management practices which reduce the risks associated with both more difficult crop establishment and higher nitrate leaching of forage legumes as compared to grass swards.

Key words: forage systems, red clover, white clover, lucerne, lotus, galega, economics, dairy farming, organic milk production, northern Europe

Introduction

Forage legumes provide the basis for grassland farming throughout much of the world. Their importance has arisen principally because of their ability to fix atmospheric nitrogen (N₂) biologically, an attribute that is seen as

especially attractive for organic livestock production. However, despite their positive attributes, their use in Europe has declined by approximately 25% over the past 20 years (Fig. 1). This paper revisits the economic case for livestock farmers in northern Europe making increased use of legume-based swards, first under conventional and then

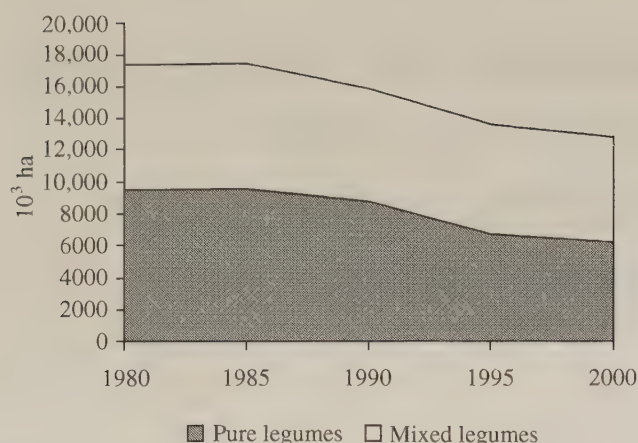


Figure 1. Trends over the period 1980–2000 in the forage area within the EU-12 under pure legumes or legumes mixed with grass or root crops. EU-12 includes the following countries: Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, UK.

under organic management. Using the yield data and animal performance figures recorded in recent experimental trials¹, conducted over 3 years (1998–2000) at 12 sites (Fig. 2) in four European countries (United Kingdom, Germany, Sweden and Finland), an economic assessment of the potential for increasing the use of forage legumes in livestock systems has been undertaken.

The first part of this paper reports on the methodology used in the economic assessment. This is followed by a discussion of the projected economic gains from replacing fertilized grass by forage legumes under conventional management. Finally, as four experimental sites in the trials (Ruukki, Finland; Lilla Böslid, Sweden; Adolphshof, Germany; Trawsgoed, UK) involved organic treatments, the third part of the paper includes an assessment of the comparative economics of organic systems of production, based on forage legumes, relative to conventional grass-based systems. As the scope of the experimental trials was confined to examining the use of forage legumes for silage fed to dairy cows, the economic assessment has been confined to examining the comparative profitability of the different forages for silage production. Although this means that the resultant economic analysis is in some sense a partial one, the importance of silage production and dairy farming in the study area makes the results very relevant.

A Methodology for Estimating the Production Costs and Economic Value of Legume Silages

Using the results from the first two harvest years of the trials², the comparative costs and benefits of growing and feeding legume silages, both as sole feeds and mixtures with grass, in place of grass silage have been examined. To undertake this economic evaluation, it was necessary to devise a framework for both costing forage production and,



Figure 2. Map of the trial sites in the four countries.

more problematically, putting a value on silage, which is not traded and so has no reported price. The underlying methodology employed in the economic evaluation of forage legumes sought to address three issues, namely:

1. What were the cost elements involved in growing and producing legume silages, and how should they be valued?
2. What were the economic values to be attached to the different legume silages?
3. How can the net financial benefits to livestock farmers of replacing grass by legume silages be objectively assessed?

In terms of estimating the costs of silage production, these were divided into three components, namely: (1) the annual costs of establishing the forage crop; (2) the annual costs of maintaining the crop; and (3) the costs of harvesting and ensiling the crop per tonne dry matter (DM). Detailed data on the operations and costs involved were collected for the UK, while comparable costs for Germany, Sweden and Finland were extrapolated using published price indices for machinery, fuel, labor and other purchased inputs in the different countries. A full description of the derivation of the costs are given in Doyle and Topp (2002)³.

Estimating the value of the silage produced was much more difficult, as very little forage legume silage is currently traded. Accordingly, two very different approaches to deriving economic values were explored. The first method ('Method 1') involved estimating the *theoretical* value by deriving the value of the silage from the value of purchased hay and concentrates substituted by feeding a kg DM of silage. The second method ('Method 2') involved estimating the *actual* value of the legume silage from the observed experimental responses in terms of milk yield⁴. While the former method is subject to errors inherent in the models used, the latter suffers from potential errors associated with measurement and variation between cows and trials. Thus, it is not possible to pronounce one

Table 1. Assumed percentage of legume by DM weight in high- and low-legume silages.

	High-legume silages	Low-legume silages
Grass-white clover	40	20
Grass-red clover	70	40
Grass-lucerne	40	10
Grass-lotus	30	10
Grass-galega	40	5

Table 2. Average total costs per kg DM of silage for the various forage crops in the UK, Germany, Sweden and Finland, € (kg DM)⁻¹.

	€ (kg DM) ⁻¹			
Silage crop	UK	Germany	Sweden	Finland
Grass	0.118	0.154	0.148	0.112
White clover	0.116	0.172	0.131	0.127
Red clover	0.107	0.119	0.123	0.113
Lucerne	0.108	0.121	0.142	0.132
Lotus	0.118	0.149	0.140	0.135
Galega	0.117	0.128	0.142	0.123
Grass-white clover	0.110	0.144	0.117	0.110
Grass-red clover	0.107	0.121	0.118	0.107
Grass-lucerne	0.109	0.123	0.127	0.117
Grass-lotus	0.113	0.135	0.124	0.121
Grass-galega	0.115	0.130	0.125	0.117

method as more accurate than the other. For this reason both methods were employed and are explained in more detail in Doyle and Topp³.

For mixed grass-legume silages, the case was more complex, since the value of the silage is not independent of its composition. In the trials, the average composition of the herbage cut for silage over the two harvest years varied for the four countries. However, consistently in the UK, the percentage of leguminous material in the cut forage was lower than at the continental trial sites. Given this, it was decided to consider the value of grass-legume silages at two different compositions. For the high-legume silages, the percentage of legume in the silage was set close to the mean of the Finnish, Swedish and German data, while the low-legume silage was equated with the levels achieved in the UK. The assumed percentage of the silage dry weight accounted for by leguminous material for high- and low-legume silages is shown in Table 1.

Nevertheless, the decision to grow forage crops is not determined by either the costs of production or the economic value of the feed, but by the profitability per hectare. To determine the comparative profitability of feeding the different silages to dairy cows, the costs per hectare were initially subtracted from the total calculated value of the ensiled crop. However, this calculation ignores the fact that, due to different forage yields and silage

Table 3. Estimated value per kg DM of silage using Method 1, € (kg DM)⁻¹.

	€ (kg DM) ⁻¹			
Silage crop	UK	Germany	Sweden	Finland
Pure silages				
Grass	0.117	0.112	0.159	0.138
White clover	0.142	0.126	0.170	0.174
Red clover	0.139	0.121	0.175	0.174
Lucerne	0.131	0.113	0.180	0.168
Lotus	0.131	0.116	0.172	0.163
Galega	0.125	0.114	0.166	0.152
High-legume silages				
Grass-white clover	0.129	0.117	0.166	0.156
Grass-red clover	0.132	0.117	0.171	0.163
Grass-lucerne	0.124	0.112	0.169	0.152
Grass-lotus	0.121	0.113	0.163	0.145
Grass-galega	0.121	0.112	0.163	0.145
Low-legume silage				
Grass-white clover	0.123	0.114	0.162	0.147
Grass-red clover	0.125	0.115	0.165	0.152
Grass-lucerne	0.120	0.112	0.162	0.143
Grass-lotus	0.120	0.112	0.162	0.143
Grass-galega	0.119	0.112	0.162	0.143

Table 4. Estimated value per kg DM of silage using Method 2, € (kg DM)⁻¹.

	€ (kg DM) ⁻¹		
Silage	UK	Sweden	Finland
Grass	0.133	0.146	0.204
White clover	0.154	0.165	—
Red clover	0.142	0.151	0.209
Lucerne	0.124	—	—
Lotus	—	—	—
Galega	—	—	0.206
Grass-white clover	0.130	0.159	—
Grass-red clover	0.143	0.146	0.206
Grass-lucerne	—	—	—
Grass-lotus	—	—	—
Grass-galega	—	—	0.199

intakes, a different number of cows per hectare can be supported by the different forage silages. To take this into account, it was necessary to estimate the opportunity cost of the land. Thus, if one forage crop required more land than grass silage to support a given herd size, then the opportunity cost of the land would measure the benefits foregone in terms of the next best alternative use for the land. In practice, deriving the opportunity cost of land was difficult, because it depended strictly on site-specific considerations. However, an approximation for it was taken to be the current annual rental value for grassland. In theory, a dairy producer in need of more land could lease additional land at this price.

Comparative Profitability of Legume-Based Systems Under Conventional Management

Using the reported national mean yields for the first and second harvest years, the costs of producing silage from pure and mixed crops of grass, white clover (*Trifolium repens* L.), red clover (*Trifolium pratense* L.), lucerne (*Medicago sativa* L.), lotus (*Lotus corniculatus* L.) and galega (*Galega orientalis* Lam.) are shown in Table 2 for all four countries participating in the trials. Specifically, the costs are expressed in € (kg DM)⁻¹ of ensiled material. There are some interesting differences between countries in the production costs of the crops. However, red clover silage consistently has one of the lowest costs of production per kg DM of ensiled material. Mixed grass-legume silages also tend to have lower unit costs of production than pure legume silages, even though grass silage tends to be the most expensive silage to produce, except in Finland.

The corresponding estimates for the value of the silage produced are presented in Tables 3 and 4. The estimates of the theoretical value of the silage, based on the nutritional value of the crop and the prices of purchased substitutes ('Method 1'), are presented in Table 3. For grass-legume silages, the values are presented for silages with low- and high-legume contents, as described in Table 1. The corresponding estimates for silage values using the alternative method for determining the value of the silage, based on silage intake and milk yield ('Method 2'), are presented in Table 4. As there were no cow feeding trials in Germany, results are only given for the UK, Sweden and Finland, and

only for those forage combinations fed. In the UK, low-legume silages were fed, whereas in Sweden and Finland high-legume silages were fed.

Except in the case of Finland, there is a reasonable measure of agreement between the two methods for valuing the silages in terms of absolute values. In general, pure legume silages have the highest economic value, with grass at the opposite end of the scale. In the case of Finland, it is apparent that the second method gives values which are about €0.03–0.05 (kg DM)⁻¹ higher. This is equivalent to €30–50 (t DM)⁻¹. Perhaps the most important difference between the two methods of estimating the economic value of the silage is with regard to grass. In general, using the second method, compared to Method 1, grass silage appears more competitive with legume silages.

However, the economic decision of growing forage crops is not determined by either costs of production or the economic value of the feed, but by the profitability per hectare. Relative to the estimated profits per hectare of grassland, Table 5 presents the projected increase in profits per hectare from growing and ensiling forage legumes, either as sole crops or mixtures with grass. The figures are based on the unit production costs in Table 2, the unit value of the feed in Table 3 and the observed mean 'national' forage yields reported in the trials. Some caution is needed in interpreting the figures, as, clearly, the methods used to derive costs and values are subject to significant assumptions. In particular, in Finland there were eight cases where the estimated value of the crop was less than the estimated costs of production, and the projected profits were negative. However, this does not invalidate the absolute differences

Table 5. Projected economic benefit from growing and feeding a legume or grass-legume silage in place of grass silage.¹ (Figures in parentheses denote the percentage increase in profits.)

Silage crop	€ ha ⁻¹ yr ⁻¹			
	UK	Germany	Sweden	Finland
Pure crops				
White clover	177.9 (17.8)	78.3 (7.8)	109.9 (11.0)	13.5 (1.4)
Red clover	292.1 (29.2)	258.4 (25.9)	220.2 (22.0)	143.6 (14.4)
Lucerne	206.6 (20.7)	151.7 (15.2)	68.6 (6.9)	-37.5 (-3.7)
Lotus	88.3 (8.8)	81.4 (8.1)	54.8 (5.5)	-70.2 (-7.0)
Galega	56.8 (5.7)	139.4 (13.9)	19.1 (1.9)	-44.6 (-4.5)
High-legume silages				
Grass-white clover	164.8 (16.5)	100.5 (10.1)	255.1 (25.5)	92.9 (9.3)
Grass-red clover	224.7 (22.5)	203.0 (20.3)	285.6 (28.6)	181.3 (18.1)
Grass-lucerne	129.0 (12.9)	146.7 (14.7)	141.5 (14.2)	2.85 (0.3)
Grass-lotus	69.4 (6.9)	105.6 (10.6)	141.7 (14.2)	-58.3 (-5.8)
Grass-galega	49.4 (4.9)	116.7 (11.7)	133.9 (13.4)	-29.1 (-2.9)
Low-legume silage				
Grass-white clover	116.7 (11.7)	85.1 (8.5)	227.7 (22.8)	44.3 (4.4)
Grass-red clover	163.5 (16.4)	186.2 (18.6)	244.7 (24.5)	115.4 (11.5)
Grass-lucerne	96.7 (9.7)	146.7 (14.7)	104.7 (10.5)	-37.5 (-3.7)
Grass-lotus	62.1 (6.2)	99.6 (10.0)	136.0 (13.6)	-66.4 (-6.6)
Grass-galega	36.0 (3.6)	116.7 (11.7)	128.3 (12.8)	-38.0 (-3.8)

¹ Value of forage derived using Method 1.

Table 6. Relative ranking of forage crops, in terms of profitability, estimated using Method 1 (1=highest value).

	LC ¹	UK	LC	Germany	LC	Sweden	LC	Finland
1		Red clover		Red clover	H	Grass-red clover	H	Grass-red clover
2	H	Grass-red clover	H	Grass-red clover	H	Grass-white clover		Red clover
3		Lucerne	L	Grass-red clover	L	Grass-red clover	L	Grass-red clover
4		White clover		Lucerne	L	Grass-white clover	H	Grass-white clover
5	H	Grass-white clover	L	Grass-lucerne		Red clover	L	Grass-white clover
6	L	Grass-red clover	H	Grass-lucerne	H	Grass-lotus		White clover
7	H	Grass-lucerne		Galega	H	Grass-lucerne	H	Grass-lucerne
8	L	Grass-white clover	H	Grass-galega	L	Grass-white clover		Grass
9	L	Grass-lucerne	L	Grass-galega	H	Grass-galega	H	Grass-galega
10		Lotus	H	Grass-lotus	L	Grass-galega		Lucerne
11	H	Grass-lotus	H	Grass-white clover		White clover	L	Grass-lucerne
12	L	Grass-lotus	L	Grass-lotus	L	Grass-lucerne	L	Grass-galega
13		Galega	L	Grass-white clover		Lucerne		Galega
14	H	Grass-galega		Lotus		Lotus	H	Grass-lotus
15	L	Grass-galega		White clover		Galega	L	Grass-lotus
16		Grass		Grass		Grass		Lotus

¹ LC refers to the legume content of the silages. 'H' denotes a silage with a high legume content and 'L' denotes a silage with a low legume content.

in profits, which do provide a measure of the relative economic attraction of growing and ensiling different forage legumes. On the other hand, it would be unwise to interpret the absolute differences too literally.

To provide some kind of reference framework for the differences in profits, these have been compared with the average national value of the grass silage crop derived from the trial data, for a sward receiving 200 kg N ha⁻¹; these figures are given in parentheses. As such, the percentage figures can be equated with the percentage increase in the value of a kg DM of grass silage that would be required for grass to be competitive with the legume-based sward. Expressing the difference in profits as a percentage of the value of the ensiled grass crop, rather than the profits *per se* from the grass crop, was considered more meaningful, largely because the estimated profits per hectare for grass silage were negative in two of the countries, as noted previously. In addition, as a residual of the difference between the value of the ensiled crop and the costs of production, profits show considerable fluctuations for small changes in the estimated crop value or production costs.

From Table 5 it is possible to prepare a ranking in terms of profitability for the different forage crops per hectare; this is presented in Table 6. This table shows a number of similarities and differences between countries in terms of the ranking of the forage crops, which may be summarized as follows:

1. Red clover and grass-red clover mixtures are consistently among the most profitable forage crops.
2. With the exception of Finland, grass alone is projected to be the least profitable forage crop.
3. With the exception of Germany, white clover, especially as part of a grass-clover ley, appears to be an attractive forage crop.

4. Lotus and galega, whether as pure crops or mixtures, are generally projected to be less profitable than red clover, white clover and lucerne.

5. Except in the UK, forage legumes generally appear to perform better as part of a grass-legume mixture than as sole crops.

The equivalent estimates of comparative profitability, based on estimates of the crop value derived from observed silage intakes and milk yields ('Method 2'), are presented in Table 7. Because of the large number of missing values, it is difficult to assess whether the change in the method of valuing the crops realistically affects the relative ranking of them. However, it is clear that the differences, relative to grass, in profitability tend to be smaller than with Method 1, and, apparently, grass has a lesser economic disadvantage. For Finland, Method 2 also increases the relative economic benefit of growing galega in conjunction with grass. Thus, the second method of valuing the forage crops produces less clear-cut evidence of the economic benefit of growing and feeding forage legumes. Nevertheless, red and white clover do tend to show some economic benefit compared to grass silage.

Profitability of Organic Legume-Based Systems

As some of the experimental sites involved organic treatments, the analysis can be extended to include an assessment of the comparative economics of organic systems of production based on forage legumes, relative to conventional grass-based systems. Basically, production costs differ because organic systems require more mechanical treatments due to the fact that they are not using any fertilizers and sprays. Ensiling also differs in that an

Table 7. Alternative projected economic benefit from growing and feeding a legume or grass-legume silage in place of grass silage.¹ (Figures in parentheses represent the percentage increase in profits.)

Silage	€ ha ⁻¹		
	UK	Sweden	Finland
White clover	112.5 (9.9)	62.7 (5.5)	-
Red clover	159.2 (14.0)	-70.3 (-6.2)	-98.8 (-8.7)
Lucerne	-94.5 (-8.7)	-	-
Lotus	-	-	-
Galega	-	-	-133.2 (-11.7)
Grass-white clover	22.8 (2.0)	186.7 (16.4)	-
Grass-red clover	152.9 (13.4)	27.8 (2.4)	76.6 (6.7)
Grass-lucerne	-	-	-
Grass-lotus	-	-	-
Grass-galega	-	-	307.2 (27.0)

¹ Value of forage derived using Method 2.

Table 8. Average total costs per kg DM of silage for organically grown forage crops in the UK, Germany, Sweden and Finland, € (kg DM)⁻¹.

Silage crop	€ (kg DM) ⁻¹			
	UK	Germany	Sweden	Finland
Grass (grown conventionally)	0.118	0.154	0.147	0.112
White clover	0.095	0.151	0.110	0.106
Red clover	0.086	0.098	0.102	0.092
Lucerne	0.087	0.100	0.121	0.111
Lotus	0.097	0.128	0.119	0.114
Galega	0.096	0.107	0.121	0.102
Grass-white clover	0.089	0.123	0.096	0.089
Grass-red clover	0.086	0.100	0.097	0.086
Grass-lucerne	0.088	0.102	0.106	0.096
Grass-lotus	0.092	0.114	0.103	0.100
Grass-galega	0.094	0.109	0.104	0.096

inoculant, rather than formic acid, is used for crop preservation. On the other hand, it is justifiable to assume similar crop yields⁵ and forage quality, as well as similar milk yields. However, the milk prices are expected to differ from those for conventional systems, due to the premium paid for organic milk. In the UK the organic milk price premium at the time of the study (2000/2001) was about 80%. The comparable premiums in Germany, Sweden and Finland were lower than those of the UK, at 40, 20 and 10%, respectively.

The corresponding costs of producing organic silage are presented in Table 8. In this case, the comparison is made with a conventionally grown crop of grass silage, receiving 200 kg N ha⁻¹. While the ranking of the legume and grass-legume silages is unchanged from that of conventionally grown forage, it can be seen that, so long as equivalent

yields to conventionally managed crops can be obtained, unit costs of production would appear to be reduced by between 15 and 20%, making grass an even less attractive crop. Alternatively, when interpreting costs, it is suggested that silage yields from organic forage legumes could be reduced by between 15 and 20%, compared to conventionally grown crops, and still be competitive with fertilized grass swards in terms of the costs of producing a given volume of silage.

With organic production systems, the value of the forage silages might be expected to increase, at least when applying the second method, due to the higher price paid for organic milk. The results when applying the organic milk price premium for the estimation of silage values for legume and grass-legume silages are shown in Table 9. In this case, the comparison is with grass silage grown conventionally, receiving 200 kg N ha⁻¹, and with no organic milk price premium. It can be seen that the relative rankings do not change, silage values for the legume forages increase by nearly €0.1 (kg DM)⁻¹ [€100 (t DM)⁻¹] in the UK, €0.03 (kg DM)⁻¹ [€30 (t DM)⁻¹] in Sweden and €0.02 (kg DM)⁻¹ [€20 (t DM)⁻¹] in Finland.

Forage legumes, with their ability to fix nitrogen biologically, are especially attractive for organic livestock production systems. Using the estimated values of organic silage in Table 9 and the production costs in Table 8, it is possible to project the economic benefits of growing and feeding organically produced forage legumes replacing grass silage. The economic benefits relative to conventional fertilized grass systems are presented in Table 10. This shows that, using forage legumes in place of fertilized grass, organic systems can apparently achieve profits in excess of those for conventional grass-based systems for selected legumes. In particular, organic systems based on red clover and white clover, whether grown as sole crops or in mixtures with grass, look especially promising, showing improvements in profits. These profits, expressed as a percentage of the value of the equivalent silage crop harvested from a grass sward receiving 200 kg N ha⁻¹, are in excess of 75% in the UK. Much the same picture is evident in Sweden, but the improvements are smaller (around 10–30%), due to the much lower price paid for organic milk. Only in Finland is there some evidence that systems based on forage legumes and organic milk production may not consistently outperform conventional grass-based dairy systems.

Discussion and Conclusions

From the economic analysis of both the trial data² and the model results from Methods 1 and 2, the following general conclusions can be made:

1. Under conventional (non-organic) management, red clover and, to a lesser degree, white clover and lucerne potentially can produce higher profits per hectare than grass-based systems using high levels of inorganic

Table 9. Estimated value per kg DM of organic silage using second method, € (kg DM)⁻¹.

Silage crop	€ (kg DM) ⁻¹		
	UK	Sweden	Finland
Grass (grown conventionally)	0.133	0.146	0.203
White clover	0.276	0.198	–
Red clover	0.255	0.181	0.230
Lucerne	0.223	–	–
Lotus	–	–	–
Galega	–	–	0.226
Grass–white clover	0.234	0.191	–
Grass–red clover	0.257	0.175	0.226
Grass–lucerne	–	–	–
Grass–lotus	–	–	–
Grass–galega	–	–	0.219

Table 10. Projected economic benefits of organic legume-based production systems relative to conventional grass-based systems of production.¹ (Figures in parentheses represent the percentage increase in profits.)

Silage	€ ha ⁻¹ yr ⁻¹		
	UK	Sweden	Finland
White clover	909.9 (80.0)	222.1 (19.5)	–
Red clover	1162.5 (102.3)	103.9 (9.1)	3.8 (0.3)
Lucerne	747.0 (66.7)	–	–
Lotus	–	–	–
Galega	–	–	–54.1 (–4.8)
Grass–white clover	855.7 (75.3)	404.2 (35.6)	–
Grass–red clover	1152.9 (101.4)	225.9 (19.9)	199.7 (17.6)
Grass–lucerne	–	–	–
Grass–lotus	–	–	–
Grass–galega	–	–	396.1 (34.8)

¹ Value of forage derived using Method 2.

nitrogen. Moreover, this result appears to be true across northern Europe.

- Legumes, such as galega and, to a lesser extent, lotus, can be economically competitive with fertilized grass crops, but will not generally be the forage legumes of choice.
- In general, from an economic standpoint, forage legumes are probably most profitable when grown in mixtures with grass rather than as sole crops.
- The use of forage legumes in organic systems, under careful management, results in higher profits per hectare than those obtained on conventional grass-based ones.

There are two caveats to these conclusions. First, in the southern parts of the region, such as France and Germany, maize (*Zea mays* L.) is a more common silage crop than grass, so that comparisons between legume-based and

grass-based systems of forage production may not be entirely relevant to livestock farmers in these regions. However, Doyle and Topp⁶ have compared the profitability of growing maize silage in place of grass silage, and observed that profits were improved by €40 ha⁻¹ yr⁻¹ in the UK and €102 ha⁻¹ yr⁻¹ in Germany. Comparing these gains with those projected for legume-based swards in Table 5, it is still evident that red clover, white clover and lucerne can compete economically with maize as silage crops.

The second caveat concerns the comparative performance of legume-based organic systems of milk production, relative to conventional dairy systems. Recently, the price premium paid for organic milk has dropped sharply in the UK. As a significant proportion of the estimated economic gains in Table 10 are connected with the milk price premium, the comparative performance of legume-based organic systems relative to conventional dairy systems are strongly related to the presumed price premium. However, a fall in the price premium for organic milk from 80 to 20% was estimated by Doyle and Topp⁷ to only reduce the gains per hectare for organic systems by €500–600 ha⁻¹ yr⁻¹. Even taking this reduction into account, legume-based organic systems still show a gain over conventional grass-based dairy systems.

Thus, this analysis confirms that, potentially, legume-based systems of forage production are economically attractive to dairy farmers in northern Europe and are central to ensuring that organic systems can compete in terms of profitability with conventional systems. However, whether forage legumes are widely adopted in the region will depend on the assessment of the risks by livestock producers. In the experimental trials, on which this analysis was based, it was clear that legume-based systems were more difficult to manage. First, forage legumes proved more difficult than grass to establish, although once established the yields appeared no more uncertain⁶. Secondly, under pure legume swards at least, nitrate leaching⁶ was found to be slightly higher than from grass swards receiving 200 kg N ha⁻¹. Especially under red and white clover, over 3 years on cut swards, nitrogen leaching losses attained 25–30 kg N ha⁻¹ yr⁻¹, compared to 5–10 kg N ha⁻¹ yr⁻¹ for fertilized grass swards. However, the environmental cost associated with this higher N leaching from legume-based systems is difficult to estimate and has not been explored in this study.

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A planning tool for integrating crop choices with weed management in the Northern Great Plains

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Abstract

Crop production in the Northern Great Plains is rapidly changing because of no-till practices; producers now grow a diversity of crops with winter wheat to increase production as well as to manage weeds. With the multitude of crops available, producers are asking for guidelines to sequence crops in rotations that help weed management. We developed a planning tool that lists various choices with crops when designing a rotation; the choices are arranged by impact on weed dynamics as quantified by research in the region. The tool includes choices among crops, such as varying crops with different life cycles, planting dates, or row spacing, and choices within an individual crop, such as varying cultivar or planting date. Choices among crops impact weeds the most, whereas choices within an individual crop are less effective and usually lead to lower crop yield. For example, rotations comprised of two cool-season crops followed by two warm-season crops can reduce weed populations six- to 12-fold. In contrast, replacing a standard-height cultivar with a taller cultivar that is more competitive with weeds, is often inconsistent for weed management, whereas crop yield may be less. Producers associated with the Northern Plains Sustainable Agricultural Society felt that the planning tool would encourage long-range planning as well as help integrate weed management with the design of cropping systems. The purpose of the tool is to encourage ecologically based weed management, which can reduce herbicide inputs by 50% for Northern Great Plains producers.

Key words: cultural practices, ecologically based weed management, rotation design

Introduction

In the semi-arid Northern Great Plains, an area that ranges from western North Dakota to northeastern Colorado and western Kansas, winter wheat–fallow has historically been the prevalent crop rotation. During fallow, neither crops nor weeds are allowed to grow, as the goal of fallow is to store precipitation in soil. Soil water gained during fallow improves growth of the following winter wheat, subsequently reducing yield variability and crop loss due to erratic precipitation.

In recent years, however, producers have changed this rotation to include more crop diversity. One reason for this change is development of no-till systems that maintain crop residue on the soil surface. No-till improves water relations¹ and soil health², such that producers can grow several crops in a row before fallowing. Producers are now growing corn (*Zea mays* L.), proso millet (*Panicum*

miliaceum L.), sorghum [*Sorghum bicolor* (L.) Moench], sunflower (*Helianthus annuus* L.), canola (*Brassica rapa* L.), and dry pea (*Pisum sativum* L.) in sequence with winter wheat and fallow^{3,4}.

Crop diversity in no-till systems offers producers a multitude of benefits, such as improved productivity and economics. With appropriate sequencing, crop yield can be increased due to the rotation effect⁵, whereas land productivity can be almost doubled with diverse rotations, compared with winter wheat–fallow³. Improved productivity increases net returns by 25–40%⁶.

No-till systems are successful because herbicides replaced tillage for controlling weeds. Yet, producers are concerned with herbicide use because resistant biotypes of several weed species are now common in this region⁷. For example, atrazine controls weeds in both corn and fallow. But now, kochia [*Kochia scoparia* (L.) Schrad.], green foxtail [*Setaria viridis* (L.) Beauv.] and barnyardgrass

[*Echinochloa crus-galli* (L.) Beauv.] are resistant to atrazine. Because of resistant weed species, production costs have increased considerably as producers are forced to use more expensive management tactics⁸.

With the diversity of crops available in this region, producers can minimize herbicide resistance and input costs with ecologically based weed management. The ecological approach emphasizes weed population management and cultural practices that enhance crop competitiveness with weeds⁹. A key strategy for reducing weed populations is to rotate crops with different life cycles¹⁰; lower weed density enhances effectiveness of cultural practices in controlling weeds, such that, in some crops, herbicides are not needed for weed management¹¹. Growing crops without herbicides reduces selection pressure for resistance as well as input costs. An additional benefit of crop diversity is that producers have more opportunities to rotate herbicides with different modes of action, further reducing selection pressure for herbicide resistance¹². Based on income tax records for farm expenses, the ecological approach has enabled producers in the Northern Great Plains to reduce herbicide inputs by 50%¹⁰.

When designing a rotation, producers consider a multitude of factors, such as choice of crops, crop sequencing and available markets, as well as strategies for soil, nutrient, time and equipment management. If rotations are comprised of only one or two crops, planning for weed management usually emphasizes choice and rate of herbicide used. With the ecological approach, however, practices that affect weed populations and crop competitiveness are included in the design of rotations.

Extensive information is available related to alternative cropping systems, crop sequencing and weed management. Yet, seldom are producers provided with a framework to organize the massive database within a specific discipline, much less at the cropping systems level. Because producers are exploring new rotations, they are asking for a guide to integrate crop choices with weed management. Our goal was to develop a planning tool that encourages the merging of ecological principles related to weed management with other factors involved in designing rotations. Our ultimate goal is to help producers manage weeds, reduce herbicide inputs and minimize development of herbicide-resistant weeds.

Planning Tool: Guidelines for Crop Choices that Help Weed Management

Our planning tool (Fig. 1) lists possible choices with crops that can be integrated into a rotation. The choices are arranged by impact on weed dynamics, with the choice of greatest impact being listed at the top; the figure visually ranks the choices in a step-like design to help the producer compare his current strategy with other possible choices. In the following text, we describe the response of weed

Vary Crops with Different Life Cycles

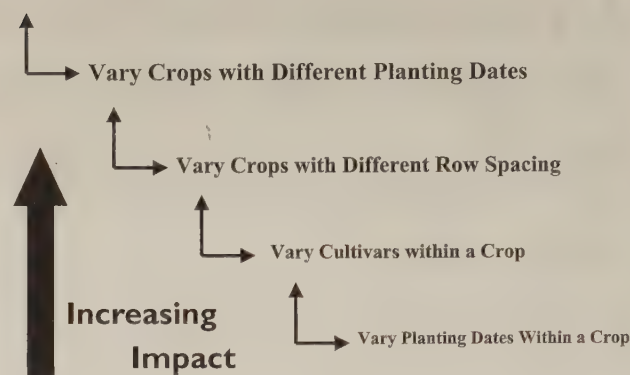


Figure 1. Planning tool to guide crop choices in relation to weed management, based on weed ecology research conducted in the Great Plains.

dynamics to each choice, based on research conducted in the Northern Great Plains.

Vary crops with different life cycles

Weed species tend to associate with crops of similar life cycles¹³, thus rotating crops with different life cycles disrupts population growth of weeds¹⁴. In the Northern Great Plains, where both winter and summer annual crops are well adapted, producers can sequence crops to accentuate life cycle differences. The impact of this strategy on weed dynamics can be striking, as shown in a long-term rotation study at Akron, Colorado¹⁰. In this study, a series of rotations was established with conventional practices used by producers in the area. After 8 years, weed biomass differed sixfold between monocultures and rotations comprised of crops with different life cycles.

A surprising finding, however, was that weed biomass was affected by crop sequence only if there was a 2-year interval between crops with similar life cycles. For example, a winter wheat–corn–proso millet rotation eliminated winter annual weeds such as downy brome (*Bromus tectorum* L.), but densities of summer annual grasses, such as green foxtail and witchgrass (*Panicum capillare* L.), increased across time. But, if rotations were comprised of two winter annual crops followed by two summer annual crops, densities of both winter and summer annual weeds were minimal.

A similar trend occurred with crop sequencing at another rotation study in central South Dakota¹⁰. After 10 years, a winter wheat–fallow rotation was infested with downy brome at 31 plants m⁻² (Fig. 2). When chickpea (*Cicer arietinum* L.), a summer annual crop, was added to the rotation (W-CP in Fig. 2), weed density increased to 60 plants m⁻²; the weed community included summer annual grasses such as green foxtail and witchgrass, as well as downy brome. A three-crop rotation comprised of one winter annual and two summer annual crops, winter wheat–corn–chickpea, eliminated downy brome but green foxtail

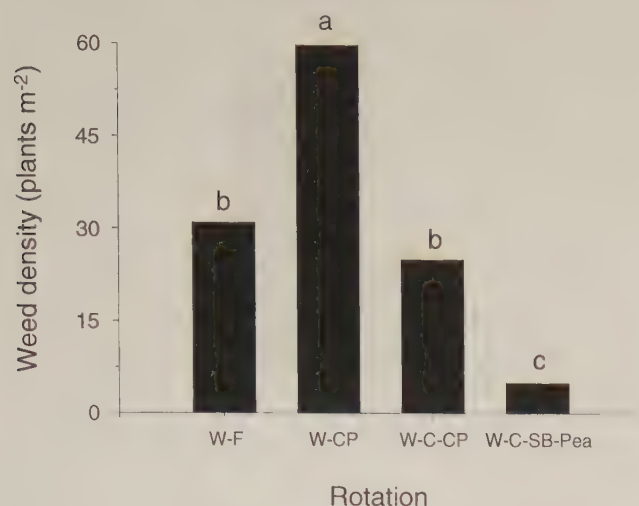


Figure 2. Weed density in four rotations of a cropping systems study at Pierre, South Dakota (W, winter wheat; F, fallow; CP, chickpea; C, corn; SB, soybean; and Pea, dry pea). The study was initiated in 1990 and data recorded in 2001 and 2002. Weeds were controlled with conventional practices during the study. Treatment means represent weed density averaged across all crops within each rotation; bars with the same letter are not significantly different based on Fisher's LSD ($P < 0.05$). (Adapted from Anderson¹⁰.)

and witchgrass density averaged 25 plants m⁻². However, a rotation comprised of two cool-season crops, winter wheat and dry pea, followed by two warm-season crops, corn and soybean (*Glycine max* Merrill), minimized weeds, such that weed density was 12-fold less compared with winter wheat–chickpea. As found in the Akron, Colorado study, lowest weed density occurs in four-crop rotations that balance cool- and warm-season crops in 2-year intervals.

The effect of the 2-year interval is related to the natural decline of weed seed density in soil. The number of live weed seeds in soil declines rapidly if new seeds are not added¹⁵. Both downy brome and green foxtail seed densities decrease to less than 5% after 2 years in soil (Fig. 3). Weed seed production can be eliminated during years of crops with different life cycles; thus a 2-year interval reduces potential seedling density in future crops by more than 95%.

In the drier areas of the Northern Great Plains, where fallow is still prominent, producers can accrue this 2-year life cycle interval with rotations such as winter wheat–corn–fallow or winter wheat–proso millet–fallow. The fallow period fits either life cycle category if weeds are controlled during fallow, thus winter wheat and fallow comprise a 2-year interval to minimize summer annual weed populations, whereas the 2-year interval of corn or proso millet plus fallow reduces density of winter annual weeds in soil.

For producers in the more humid areas of the Northern Great Plains, this life cycle benefit on weed management can be further enhanced by including perennial forages in

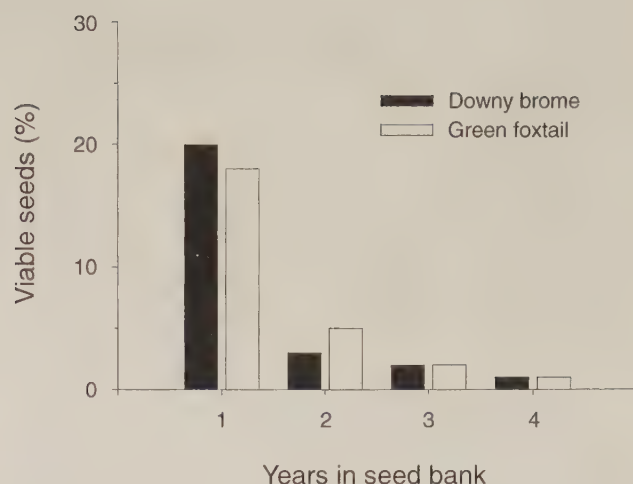


Figure 3. Longevity of green foxtail and downy brome seeds in the seed bank, when seed remains within the top 3 cm of soil. (Adapted from Anderson¹⁰.)

rotation with annual crops¹⁶. Mowing for forage harvest prevents seed production of most weeds, thus favoring decline of weed seed densities in soil during the forage interval. Lafond et al.¹⁷ suggested perennial forage intervals of 3–5 years for maximum benefit with suppressing weeds, maintaining forage stands and improving yields of following crops.

But some species, such as green foxtail, are able to produce seeds in conventional harvesting schedules with perennial forages¹⁸. With these species, perennial forages may not reduce seed density in soil. Another trend with weed dynamics in perennial forages is that winter annual weeds, such as dandelion [*Taraxacum officinale* (Weber in Wiggins)], field pennycress (*Thlaspi arvense* L.) or downy brome, may proliferate because of their earlier growth than most forages, which allows plants to establish and produce seeds.

Vary crops with different planting dates

Producers can also help weed management by rotating crops with similar life cycles but different planting dates¹⁹. For example, the weed community in northeastern Colorado displays two peak periods of emergence (Fig. 4); the first peak represents cool-season weeds, such as kochia [*Kochia scoparia* (L.) Schrad.] and Russian thistle (*Salsola iberica* Sennen & Pau), whereas warm-season weeds, such as green foxtail, witchgrass and pigweed species (*Amaranthus* spp.), emerge during the second peak, in late May and early June²⁰. Corn in this region is usually planted in early May, whereas sunflower or proso millet are planted in early June. Later planting of sunflower or proso millet in the year after corn allows producers to control summer annual weed seedlings that emerge between May 1 and early June, which is 63% of the seasonal emergence between May 1 and August 1 (Fig. 4).

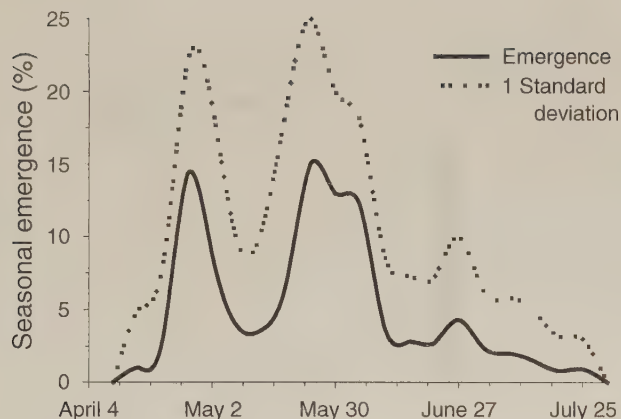


Figure 4. Weed community emergence pattern for a semi-arid site at Akron, Colorado. The weed community consisted of 16 plant species; data were collected from two tillage treatments—no-till and tillage with a sweep plow—and averaged across 7 years. The dotted line represents one standard deviation. (Adapted from Anderson²⁰.)

However, reversing this sequence, by planting either proso millet or sunflower before corn, is not effective because of extensive volunteer crop plants infesting corn. Our rotation study at Akron, Colorado included a winter wheat–proso millet–corn–fallow rotation; we terminated that rotation after 6 years because of difficulties in controlling volunteer proso millet in corn. The emergence period of volunteer proso millet ranges from early May through June, leading to volunteer densities that required higher herbicide inputs to avoid yield loss in corn.

The contrast in planting dates of winter wheat and dry pea also favors weed management, provided that dry pea precedes winter wheat in the rotation. Winter annual weeds such as downy brome, jointed goatgrass (*Aegilops cylindrica* Host), and blue mustard [*Chorispora tenella* (Pallas) DC] emerge mainly between September and March. Dry pea is planted in late March or early April, thus winter annual weeds can be controlled easily before planting. If seedlings of these weeds emerge after dry pea planting, seed production is drastically reduced because of less plant growth and inconsistent vernalization. The early growth and canopy development of winter wheat minimizes the impact of dry pea volunteers that emerge in April or May. However, if dry pea follows winter wheat, volunteer wheat seedlings will require additional control tactics in dry pea. With the proper sequence, rotating crops with different planting dates within the 2-year life cycle interval can enhance the impact of rotation design on weed dynamics.

Vary crops with different row spacing

An ecological principle related to plant competition is that the first plant to capture resources gains a competitive edge²¹. One strategy that favors resource capture is to plant crops in narrow rows, as demonstrated in a study that

compared weed growth in corn, sunflower and proso millet²². Corn was planted during the first week of May and in rows spaced 76 cm apart. Sunflower and proso millet were planted in early June; row spacing was 76 cm for sunflower and 20 cm for proso millet. Weeds, primarily green foxtail and witchgrass, were allowed to grow for 7 weeks in each crop, then harvested for biomass. Weed biomass in sunflower was only 35% that of corn (Fig. 5), reflecting the difference in weed density due to later planting of sunflower. Narrow rows with proso millet reduced weed biomass almost threefold compared with sunflower. Combining two management choices, such as selecting a crop grown in narrow rows and planting the crop later, impacted weeds tenfold, as shown with proso millet and corn.

In the Northern Great Plains, crops planted in wide rows, such as corn and sunflower, are not competitive with weeds¹⁰, but equipment technology is evolving such that these crops now can be planted in narrower rows; this practice, when combined with other cultural practices, improves their tolerance of weeds. At Akron Colorado, corn grown at 47,000 plants ha⁻¹ in narrow rows (50 cm), with N fertilizer banded by the seed, reduced weed biomass by 60% compared to the conventional system of 38,000 plants ha⁻¹ planted in 76 cm row spacing and with N broadcast²³. Because of reduced weed growth, corn yield loss due to weeds was reduced fourfold with the narrow row production system.

Vary cultivar within a crop

Cultivars differ in their competitiveness with weeds. Challaiah et al.²⁴ found that downy brome biomass production varied by 35% among winter wheat cultivars; cultivar traits associated with competitiveness were high tiller density and plant height. Winter wheat yield loss due to downy brome interference also varied twofold, with less yield loss in taller cultivars. Similar trends were found with proso millet competition with redroot pigweed (*Amaranthus retroflexus* L.); taller cultivars reduced weed growth and tolerated weed interference with less yield loss¹¹.

This strategy has some limitations. First, taller cultivars usually yield less because resources are invested in extra plant stem biomass²⁶. Secondly, cultivar impact on weeds is not consistent over years, varying with environmental conditions and time of weed emergence²⁷. Also, in years where weed density is low, producers may sacrifice crop yield with taller cultivars when weed suppression is not needed.

However, impact of cultivar choice on weed management can be improved by integrating this tactic with other cultural practices to strengthen the crop's canopy. For example, the competitiveness of winter wheat with jointed goatgrass was increased sixfold by combining a tall cultivar with higher seeding rates and nitrogen placement²⁵. Seed production of jointed goatgrass and

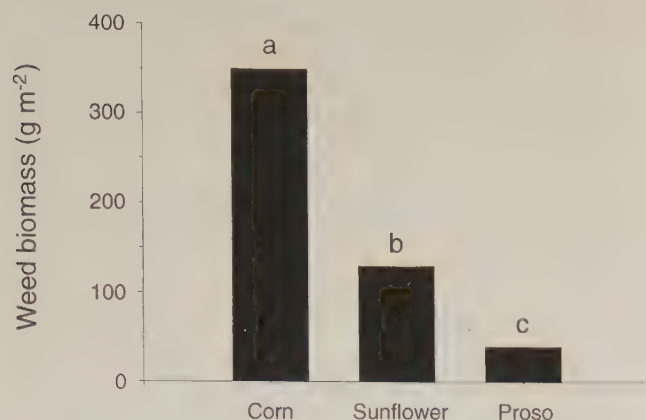


Figure 5. Weed biomass in corn, sunflower and proso millet. Biomass was determined 7 weeks after crop emergence; data were averaged across 3 years. Treatment bars with the same letter are not significantly different based on Fisher's LSD ($P < 0.05$). (Adapted from Anderson²².)

feral rye (*Cereale secale* L.) was reduced by 40–45% with this cultural approach compared to conventional practices with winter wheat (Fig. 6). Similar results occur with proso millet; adding other cultural practices to tall cultivars improves proso millet competitiveness with pigweed species several-fold²³. Furthermore, with both species, the cultural approach improves competitiveness of short cultivars such that weeds can be suppressed without sacrificing crop yield, as occurs with the taller cultivars.

Vary planting dates within a crop

A common strategy used by producers for weed management is to delay planting of the crop. This strategy allows more time for weed seedlings to emerge and be controlled before planting. However, this tactic is not consistently effective, especially in semi-arid regions with erratic rainfall. In Colorado, delayed planting of winter wheat was effective in controlling downy brome in only one year out of six²⁸. Yet, winter wheat yield was reduced every year due to late planting. The later planting of winter wheat reduces yield because the crop is more vulnerable to plant diseases and environmental stresses²⁹. Similar yield loss with delayed planting also occurs with proso millet³⁰, corn³¹ and sunflower¹⁰.

Effectiveness of delayed planting with a crop contrasts with the impact of varying crops with different planting dates. Rotating crops with different planting dates avoids the detrimental impact on yield with delayed planting of a crop, yet still reduces weed density. Delay of planting within a crop may be effective if rain occurs right before planting; by waiting, producers can eliminate the first flush of weeds that emerge. Otherwise, weed management will benefit more from choices involving different crops.

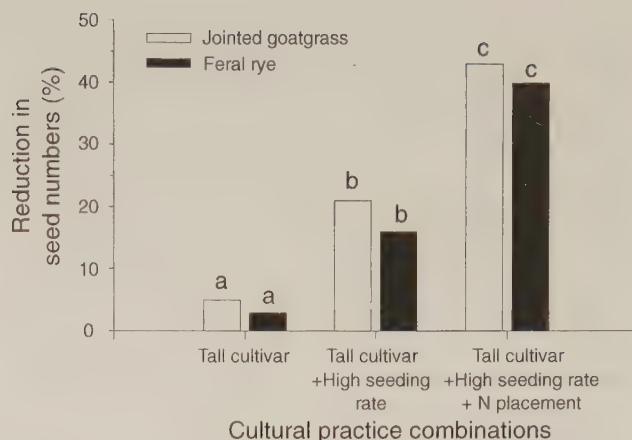


Figure 6. Seed production of jointed goatgrass and feral rye as affected by cultural practices in winter wheat, Akron, Colorado. Treatment means were compared to the conventional system of winter wheat production: semi-dwarf variety, normal seeding rate, and N applied broadcast. Data averaged across 3 years; bars with the same letter are not significantly different based on Fisher's LSD ($P < 0.05$). Means for the tall cultivar did not differ from those of the conventional system. (Adapted from Anderson²⁵.)

Impact of Crop Management Choices on Weed Dynamics

Producers can enhance weed management by crop management choices; note the six- to 12-fold impact of rotating cool- and warm-season crops in a 4-year cycle. Also, diversifying crops within a life cycle interval, such as summer annual crops, can lead to a three- to fourfold impact on weed dynamics. Sequencing crops with different planting dates and row spacing, such as corn and proso millet, can reduce weed biomass tenfold. The options available for an individual crop, such as varying cultivar or planting dates, have a minor impact on weed management; in most cases, results may be ineffective whereas crop yield may be sacrificed.

Producer Response to the Planning Tool

We presented this planning tool to members of the Northern Plains Sustainable Agriculture Society during their national meeting in 2002. This Society is comprised mainly of organic producers who rely on cultural practices to manage weeds. The producers felt that the tool would be useful in planning cropping systems, especially with the arrangement of strategies based on impact. An intriguing observation was that most producers in the Society were using choices within an individual crop, either changing cultivar or planting date, for weed management. During our discussion, they recognized that their current weed management approach was reactive, responding to weed problems as they developed rather than planning rotations to manage weed populations. The producers encouraged us to

pursue development of this tool to encourage thinking on ecological principles and long-range planning.

One producer suggested relating how strategies in ecological weed management will affect insects and plant diseases. A general principle related to pest management is that crop diversity generally favors crops over pests. For example, diversifying crops in a rotation reduces the frequency a crop is grown; plant diseases proliferate if a crop is grown too frequently. In the Great Plains, sunflower, corn and winter wheat yield the most if grown only once every 4 years, reflecting lower disease incidence¹⁰. With winter wheat, Cook and Veseth²⁹ reported that delayed planting increases the susceptibility of wheat to root diseases. They suggested that producers will improve disease management more with other practices, such as diverse rotations and fertilizer placement, and encouraged producers not to delay planting for disease management.

Andow³² found that plant insects, particularly those with limited host ranges, tended to be less abundant in diverse cropping systems. He suggested that crop diversity increases the populations of natural enemies of insect pests. With weeds, diversifying the rotation had the greater impact on population management (Fig. 1); similar results should occur with insects and plant diseases, as crop diversity is a key component of their management also.

A key to successful pest management from an ecological perspective is to integrate management tactics into the design of cropping systems³³. Our goal with this planning tool is to help producers recognize crop choices and sequences that help weed management. With the multitude of crops now available in the Great Plains, producers can develop rotations that not only improve weed management, but also accrue additional agronomic and economic benefits with crop diversity in this semi-arid region¹⁰.

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Wheat farming in Syria: An approach to economic transformation and sustainability

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Research Paper

Abstract

Sustainability has recently become an ingrained concept in crop production systems worldwide, and is the cornerstone of research programs of the global network of research centers operated by the Consultative Group of International Agricultural Research (CGIAR), which functions in collaboration with the various national agricultural research systems. One of the major CGIAR centers, the International Center for Agricultural Research in the Dry Areas (ICARDA), focuses mainly on dryland agriculture, but increasingly on irrigation, in its mandate area of West and Central Asia and North Africa. ICARDA has collaboration programs with its host country, Syria, the cradle of civilization and of settled agriculture, and the center of origin of many of the world's major crops, notably cereals and pulses. Wheat is, and has been, the most important commodity food in Syria. The Center's goal is to enhance wheat productivity in a sustainable manner for the benefit of the country's resource-poor farmers and society as a whole. Wheat is grown on about 1.5 million ha or 27% of the total cultivated land in Syria, mainly under rainfed conditions (300–500 mm annual rainfall), which are increasingly experiencing supplemental irrigation, while drier (<200 mm) areas are fully irrigated. Improved cultivars generally combine high yield potential and stress tolerance and tend to have high yield stability, being input-efficient under limited resources in stress environments and input responsive under favorable environments. Such varieties are tested under farmers' conditions through multi-year multi-locations. Other aspects of the ICARDA–Syrian collaboration wheat program include improved tillage, with an emphasis on conservation systems, adequate fertilization, and improved agronomic practices, e.g., early sowing in relation to rainfall conditions, optimum row spacing and plant population, and adequate weed control. This vigorous collaborative research–technology transfer program has produced a major shift in wheat production in Syria, from traditional low-input practices with landrace or improved cultivars to widespread adoption (two-thirds of wheat area) of modern cultivars along with improved production technology. As a result of such efforts, national income has substantially increased, and Syria has become a net exporter of wheat. Thus, the collaborative efforts of an international research center and its host country have shown clearly that there is an alternative to a traditional, low-output agriculture and its associated ills.

Key words: Syrian agriculture, wheat production technology, rainfed and irrigated cropping

Introduction

Now that we are into the Third Millennium, humankind is probably better fed than at any time in history, notwithstanding the substantial growth in the world's population, especially in developing countries¹. Nevertheless, major disparities exist, with most developed countries having food surpluses and their attendant economic implications, while large segments of the

world, especially Africa, are plagued by declining per capita production and consequent hunger and malnutrition. While agricultural research has contributed largely to helping the world feed its 6 billion people, the question is 'Can it continue to produce the spectacular achievements as in the past?' Even if we can move off the global crop production plateau, can it be done without causing irreparable damage to the very resource base that sustains agriculture?

Thus, the concept of 'sustainability' has emerged in the agricultural and social science literature. While definitions of sustainable agriculture are many and varied², most of them center around 'the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the natural resource base and avoiding environmental degradation'. Sustainable agricultural systems are designed to use existing soil nutrient and water cycles, and to harness naturally occurring energy flows for food and feed production^{3,4}. What is anathema to sustainability is resource degradation that can occur in the production process, e.g., soil erosion, declining water quality and loss of biodiversity.

The origins of settled agriculture can be traced to the Middle East, indeed most of the major food crops of the world, including wheat, evolved there. Today the region is beset with the dilemma of feeding its burgeoning populations in a resource-poor, environmentally harsh environment⁵. The irony is that this food-deficit area of the world was once the cornucopia of plenty. Notwithstanding the daunting challenges facing agriculture in the region—especially the southern and eastern fringes of Mediterranean Sea—much hope has been pinned on agricultural research as a means of transforming traditional agriculture to a modern, more productive and environmentally friendly version.

The establishment of the International Center for Agricultural Research in the Dry Areas (ICARDA) in Aleppo, Syria, in 1977, reflected the hopes for agricultural research to deliver positive change to its mandate region of North Africa and West Asia, and specifically the host country, Syria. ICARDA is one of 16 autonomous agricultural research centers worldwide that are operated under the auspices of the consultative Group for International Agricultural Research (CGIAR) based in Washington, DC. The overall goal of this global network of centers is to promote sustainable agricultural development in poorer countries of the world, leading to poverty alleviation and environmental protection. All centers operate in collaborative mode with the national agricultural research systems in their respective mandate areas.

ICARDA has particularly strong links with regional scientists, especially within Syria, where it has formal agreements and active research and technology transfer programs with various departments within the Ministry of Agriculture and Agrarian Reform. While the Center is concerned with all aspects of dryland agriculture—cereals, pulses, forage crops, animal husbandry, natural resources (land, soil, water) and biodiversity—a major focus has been, and continues to be, on wheat, both winter/spring wheat (*Triticum aestivum* L.) and hard or durum wheat (*T. turgidum* var. *durum* L.). This paper reviews briefly wheat production trends in Syria, constraints to achieving sustainable self-sufficiency and strategies to improve wheat genetically and develop better soil and crop management.

Wheat Production

Wheat is the most important commodity food in Syria in terms of area and importance, since it is the major source of energy and protein in the local diet. Bread derived from wheat is a staple 'staff of life' in Syria, which has one of the world's highest per capita consumption figures. Currently, about 1.5 million ha, equivalent to 27% of the total cultivated land in Syria, are sown to wheat. Rainfed wheat is mainly grown in the relatively wetter areas (300–500 mm annual rainfall) as well as dry areas (<200 mm) that are irrigated⁶. Supplemental irrigation is increasing in former rainfed areas, where water sources, either from surface or groundwater, are available⁷.

Fifty years ago, Syria was self-sufficient in wheat. Expansion of the wheat-cultivated area allowed Syria to be a net exporter until the 1950s. However, because of growth in domestic demand due to population increase (over 3% and one of the highest levels of population growth in the world), which was accompanied by a parallel increase in wheat yield and/or the area planted to wheat, Syria did not produce any surplus in the late 1980s, and had to import wheat and flour; for instance, the self-sufficiency rate for wheat during the period 1985–89 was about 72% of the total domestic requirement⁸.

Recognizing the urgency of the situation, Syria's agricultural policy has, since the 1990s, paid special attention to wheat production. In order to improve producers' living standards and to achieve self-sufficiency, government planning concentrated on improving the productivity of the existing wheat land. Emphasis was placed on adopting modern stress-tolerant improved wheat varieties, and using chemical fertilizers and weed and pest control measures suitable for Syrian conditions. Extension and credit institutions were organized to fulfill these requirements, while farmers were encouraged, through subsidies and price controls, to mechanize production. The government also initiated various infrastructural projects to provide irrigation facilities; water wells and other on-farm irrigation systems were developed by both the public and the private sector. The appropriate price policy for inputs and outputs contributed to encouraging farmers to adopt the new agricultural wheat technologies. Modern approaches to production, e.g., mechanical tillage, planting and harvesting, use of stress-tolerant varieties, fertilizer application, chemical weed and pest control and optimum crop rotation, have become common to most farmers.

This newly adopted strategy is reflected in the rise of wheat yield per unit area and wheat self-sufficiency; since 1993 total wheat production has exceeded domestic needs. The value of this increase is currently about US\$400 million; of this figure, 32% is attributed to improved varieties, 18% to fertilizer, 27% to irrigation and 23% to better land and crop management. About 30% of the impact came from fully irrigated areas, 30% from supplemental irrigation areas and 38% from rainfed areas.

In this context, it is pertinent to examine the role of international centers such as ICARDA and CIMMYT (Central International Center for Maize and Wheat Improvement, Centro Internacional de Mejoramiento de Maiz y Trigo), in collaboration with Syrian institutions, in spearheading research that has improved, and continues to improve, wheat production in Syria.

Development of Stress-Tolerant Varieties

Genetic factors, such as resistance or tolerance to biotic and abiotic stresses, are critically important for wheat improvement programs aimed at identifying new wheat cultivars with better yield, yield stability, quality, disease resistance and tolerance to abiotic stresses than the varieties currently under cultivation⁹.

The breeding methodology followed by ICARDA/CIMMYT emphasized a targeted crossing program aimed at broadening the crop genetic base by selective exploitation and utilization of exotic material and landraces, and by multi-location testing to expose the germplasm to the prevailing biotic and abiotic stresses throughout the wheat-growing areas of Syria. The cropping zones are dictated by rainfall: zone A (>350 mm), mainly wheat; zone B (250–350 mm), mixed cereals, legume rotations, fallow; zone C (<250 mm), barley and fallow. Selected cultivars adapted to each wheat cultivation zone in Syria generally combine high yield potential and stress tolerance and hence high yield stability¹⁰.

This feature is the result of being input-efficient under limited resources in stress environments and input responsive under favorable environments. In addition, durable resistance from proven resistant sources is bred into these cultivars to give long-term crop protection against major diseases, particularly rusts, thus reducing the use of potentially environmentally harmful chemicals that are used to control wheat diseases¹¹.

Adoption of Improved Varieties

Stress-tolerant wheat varieties accounted for about 8% of the total wheat area in 1973; most were used in irrigated areas, i.e., 41% compared to 5% in rainfed areas. Some of the earliest varieties introduced to Syria were officially reclassified as local varieties and were later replaced by improved varieties, e.g., Mexipak. After 1973, the pace of varietal development quickened, with 14 new releases (eight durum, six bread wheat, by 1993). To a limited degree, the varieties were targeted to different environments, e.g., 300–500 mm rainfall zone or full irrigation. Fertilizer use was based on zones rather than varieties and yield potential or soil test levels, although criteria are now available upon which to base nitrogen (N) and phosphorus (P) fertilizer application rates¹². Seed is multiplied by the General Organization for Seed Multiplication, under contract to producers, and made available to farmers; it is usually treated for seedborne diseases and pests before sale.

The wheat yield of stress-tolerant varieties was higher, at the national level, than local varieties, under both rainfed and irrigated conditions. Although stress-tolerant wheat varieties were superior to local wheat cultivars in rainfed areas, the largest contributor to increased wheat production in Syria is the combination of stress-tolerant varieties and irrigation. A significant milestone in wheat development in Syria was the first durum wheat line developed by ICARDA in 1983, a derivative of a cross from CIMMYT, approved by the national program and released after 4 years to farmers as a new variety, i.e., Waha, under the name of Cham 1. This was the first in a series of Cham (old Arabic name for the greater Syrian region) varieties (Cham 1 to 6) developed since then by ICARDA, all of which outyielded the older Mexipak standard variety. Some of the new varieties were targeted to specific environments, e.g., Cham 1 in drier areas (<350 mm) and Cham 2 in wetter areas and with irrigation. These varieties are grown in about two-thirds of the total wheat area in Syria.

Improved Soil and Crop Management Practices

Until recently, cultivation practices in the Middle East were traditional and primitive—having changed little for centuries, e.g., animal traction, hand sowing, little or no fertilizer, except manure, manual weed control and harvesting and threshing. Research in the region, including Syria, by ICARDA and the national programs demonstrated the advantages of improved management in terms of early sowing, establishment of early canopy cover, adequate plant population and row spacing, suitable tillage and chemical weed control¹³. Indeed, considerable efforts are now being made to promote soil-conserving, lower energy-requiring conservation tillage systems⁴.

The time of sowing was one of the most contentious issues, given the variability in rainfall, especially at the break of season. If rain after crop emergence (November–December) is not adequate, complete crop failure can occur. Nevertheless, on average, delaying sowing was estimated to reduce yield potential by 4% for each week after early November¹⁴.

A major factor in wheat yield increases in the past few decades has been the use of fertilizer. Syrian soils are inherently low in available P due to high pH and calcium carbonate (CaCO₃) contents¹⁵. Much of the early soil fertility research by ICARDA and national partners demonstrated the value of P fertilization, especially with banding¹². Similarly, N fertilization was another indispensable component of crop management¹⁶. As elsewhere, a significant portion of current yield levels is attributed to fertilizer use.

That both N and P fertilizers are now well adopted by Syrian farmers is largely due to extensive multi-year (4 years), multi-location (70 sites) research–technology transfer trials across the main rainfall zones in northeastern Syria¹⁷. In these trials, response to N was directly related to

rainfall, while response to P was relatively higher as rainfall decreased¹⁸. Thus, recommendations for fertilizer application rates are guided by rainfall zones.

Irrigation: Full or Supplemental?

When ICARDA was founded in 1977, most of Syrian cropland was rainfed, except where irrigation was possible near the Euphrates River, and to a lesser extent from underground water. The intervening years have witnessed a dramatic increase in irrigation, especially from pumping of groundwater and from newly developed projects involving surface sources. Given declining water resources, the current focus is on sustainable use of water in agriculture; thus, the concept of supplemental irrigation, i.e., stabilizing acceptable crop yields by judicious amounts of water during the growing season⁷.

A large-scale 4-year trial with both bread wheat and durum wheat at ICARDA's main station at Tel Hadya demonstrated the value of supplemental or 'deficit' irrigation^{19,20}. Average grain yield increases were 400% in a dry year (234 mm) with 180 mm irrigation water; 150% in a medium year (316 mm) with 125 mm water; and 30% in a high-rainfall year (504 mm) with 75 mm water. The widespread adoption of supplemental irrigation (40% of rainfall area in 1996) has been a major factor in the increase of wheat yields from 1.25 to 3 t ha⁻¹. Over half of the national average wheat output of 4 million tonnes is attributed to irrigation combined with improved varieties. Following a season of above-average and well-distributed rainfall (478 mm versus 330 mm on average at Tel Hadya Research Farm of ICARDA), the cereal forecast for 2002–2003 is estimated to be a record 6 million tonnes.

Sustainable Crop Management with Rotations

As desirable as it is to have high wheat output, it is equally important that the elevated level of production be sustained without detriment to the productive capacity of the resource base, i.e., soil²¹. While no land can sustain high crop yields indefinitely without inputs, practices such as rotations can contribute to yield sustainability²². Historically, in the Middle East, alternating cereal cropping with fallow helped ensure acceptable yields, largely by breaking the cereal disease cycle and improving water-use efficiency²³. The use of legumes in place of fallow has also been practiced.

The past few decades have witnessed a drastic decrease in fallow land in Syria, due to increased land-use pressure from population growth. This has given way to continuous cropping, an alarming trend with an obvious threat to sustainability². From its inception, most of the research at ICARDA focused on solving this dilemma with the outcome of long-term rotation trials²². The conclusions from several cropping systems trials offer viable alternatives to monoculture²⁴. It was demonstrated that total output from the rotation could be increased by including

feed and forage legumes²⁵. Specifically, lentil with wheat was most economic; water use in the system was optimized by legumes; and N-use efficiency was enhanced. By comparison with continuous cropping, all alternatives considered performed better in terms of yield²². These encouraging observations confirmed those from various other cereal rotation trials in the Mediterranean.

While the benefits of rotations are well known in terms of disease and weed control, limited observations from ICARDA trials indicated that the cereal-cyst nematode (*Heterodera avena*), take-all (*Gaeumannomyces graminis* var. *tritici*) and the wheat ground beetle (*Zabrus tenebroides*) all decreased in incidence with a legume/cereal rotation compared with continuous cropping with wheat.

An unintended outcome of these trials was the positive effect of some forage legume rotations such as vetch (*Vicia sativa*) and medic (*Medicago sativa*) on soil organic carbon content²⁶. Thus, an improved production system also had environmental spin-off by increasing carbon sequestration and thereby contributing to mitigating global warming. The added organic matter was also associated with improved soil physical structure. It was of interest to note that while fallowing once every 2 years maintained crop yields, the practice was associated with the lowest organic matter levels, presumably as a result of mineralization during the fallow year with no root biomass input.

Much of what has emanated from the long-term wheat trials on-station has been tested in farmers' fields for potential adoption. The past few years have witnessed a rapid expansion of vetch-growing in place of fallow or continuous wheat in northern Syria, a practice that not only puts cereal production on a sound footing but also promotes animal output—the other major component of traditional Syrian agriculture. With wider adoption of legumes, such as vetches, in cereal cropping²⁷, the impact on national output will, in all probability, be considerable.

Conclusions

This brief report highlighted a major shift in wheat production in a typical developing country in terms of its traditional agriculture and overall economic development. The catalyst to such change was the establishment of an international agricultural research center, ICARDA, the strategy of which was to work in collaboration with scientists from the various national programs in its mandate region of North Africa and West Asia. The intensive programs with Ministry of Agriculture and Agrarian Reform staff in Syria tackled all aspects of dryland cropping and, recently, with increasing emphasis on irrigation and water use. The research involved was both basic and applied, with a large capacity-building and technology-transfer component. With an initial focus on experimental station work across the range of rainfall zones (200–500 mm), later emphasis was on farmers' fields and farmer involvement in technology assessment.

The twin research approaches involved *breeding for improved germplasm* (yield stability, drought and disease resistance/tolerance) and *improved management* (agronomy, fertilization, mechanization). The doubling of wheat output in Syria within two decades, and the transformation from a food-deficit economy to a self-sufficient one, which is now exporting wheat, is testament to the success of this collaborative research partnership. While many of the technologies or practices are largely implemented, others, such as adaptation of legume/cereal rotations, are likely to impact at the national level in future.

The strategy adopted in Syrian agriculture can serve as a model for development elsewhere. The approach was one of examining traditional low-output agriculture and promoting an alternative modern package of practices, and, in so doing, it involved an alternative way of thinking on the part of farmers and administrators, as much as anything else.

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Profitability of organic cropping systems in southwestern Minnesota

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Abstract

In spite of concerns, Minnesota's dominant cropping system is the corn–soybean rotation using synthetic pesticides and chemically processed fertilizers. Using experimental data from 1990–99, this study compared the profitability of organic versus conventional strategies. Net return (NR) was calculated from actual yields, operations, inputs, prices and organic premiums. Yields and costs were lower for the 4-year organic strategy. With premiums, the 4-year organic strategy had NRs significantly higher than conventional strategies; without premiums, the NRs were statistically equal ($P=0.05$). Thus, the 4-year organic strategy was not less profitable nor its NR more variable than the conventional strategies in this study.

Key words: net returns, Variable Input Crop Management Systems, high-purchased inputs, low-purchased inputs, organic inputs, cumulative distribution functions, organic premiums, risk, first-degree stochastic dominance, second-degree stochastic dominance

Introduction

By most measures, crop production systems are more efficient and productive today than at any time in the past. This is due, in large part, to improved crop varieties, improved farm equipment, better management skills, synthetic pesticides and chemically processed fertilizers. While the use of synthetic pesticides and chemically processed fertilizers has contributed significantly to gains in productivity, it has also raised concerns from the general public about food safety and adverse environmental quality effects. In addition, the current price and income situations have increased farmers' interest in organic production methods.

However, the vast majority of farmers in southwest Minnesota (and the Midwest) continue to produce crops with a traditional corn–soybean rotation using production practices that involve, at some level, chemical use and commercial fertilizers. Farmers' reasons for not changing from traditional cropping systems are as diverse as the farmers themselves. Some of the reasons include the

uncertainty of the profitability of organic systems, increased labor that may be required by an organic system, lower yields with other systems, the cost in money and time to learn other systems, and the difficulty of finding markets for organic products.

Previous studies have analyzed the profitability, sustainability and yields of organic farming practices, and have shown generally that organic systems can be as, or more, profitable than conventional systems^{1,2}. Although price premiums paid for organic products increase profitability and are highly sought after, Welsh found in his research review that they were 'not always necessary for organic systems to be competitive with or outperform conventional systems'². However, these studies also found that organic systems were not necessarily without potential pitfalls and not necessarily for every farmer and farm site.

In response to the concerns about the impact of conventional farming practices, the University of Minnesota started the Variable Input Crop Management Systems (VICMS) study in 1989, to estimate and compare the agronomic and economic impacts of organic production

methods in southwest Minnesota. To help decrease some of the uncertainty regarding profitability of organic production methods, this current study used data from the VICMS study to compare the profitability and riskiness of three different management strategies, two cropping sequences and three organic price scenarios. The value of this study comes from the use of a long-term study (10 years) in which each crop in each management strategy and each sequence is present and replicated three times in each year. Due to the continued dominance of conventional production systems, the current study's primary objective was to test the hypothesis that conventional systems were more profitable and/or had less risk than organic systems.

Background

Sales of organically grown products have increased steadily over the past two decades³. Even though the numbers are small relative to the entire food market, the number of organic products on grocers' shelves and the amount of grocery shelf space being devoted to organically produced products has increased. As consumers become more concerned about food and environmental safety, they also become more concerned about the practices and inputs being used to produce the food they consume. Since some consumers are willing to pay a premium for products produced by organic methods, there appears to be a separate demand for organic products in the marketplace. In addition, as Krissoff (1998)⁴ notes, 'increasing farm, agribusiness, and food marketing investments in alternatively produced products suggest a responsiveness to the growing interest in the organic foods'.

In general, organic systems do not use synthetic pesticides and chemically processed fertilizers, and have longer crop sequences with a greater variety of crops being grown. However, the specific methods, certification of organic methods, and labeling of organic products were not uniform across the US until the National Organic Program (NOP) rules were finalized in December 2000, and fully implemented in October 2002. Under the NOP rules, all organically labeled products must be produced and processed using a set of specific standards, to ensure consistent practices nationwide. Organic producers must operate under an organic system plan approved by an accredited certification agency or agent. Under these standards, if a product is to be sold and labeled as organically produced, all materials used in production must be used in accordance with the National List of Allowed Synthetic and Prohibited Non-Synthetic Substances. Specifically, the NOP crop production standards⁵ state that:

Land will have no prohibited substances applied to it for at least 3 years before the harvest of an organic crop. The use of genetic engineering (included in excluded methods), ionizing radiation and sewage sludge is prohibited. Soil fertility and crop nutrients will be managed through tillage and cultivation practices, crop

rotations, and cover crops, supplemented with animal and crop waste materials and allowed synthetic materials. Preference will be given to the use of organic seeds and other planting stock, but a farmer may use non-organic seeds and planting stock under specified conditions. Crop pests, weeds, and diseases will be controlled primarily through management practices including physical, mechanical, and biological controls. When these practices are not sufficient, a biological, botanical, or synthetic substance approved for use on the National List may be used.

Study Location and Design

The VICMS study was situated at the University of Minnesota's Southwest Research and Outreach Center near Lamberton, Minnesota, about 240 km southwest of Minneapolis-St. Paul. In this area of Minnesota, crop production began in the 1870s, with wheat grown almost exclusively. From the 1900s until the 1960s, corn, small grains and pasture predominated. Since the 1960s, this region has been farmed almost exclusively with corn and soybean. Recently, corn and soybean were grown on more than 90% of the cropped land in southwest Minnesota⁶.

The data for this study were from part of the study called VICMS II, which had been cropped according to university recommendations since 1959, resulting in high soil fertility levels and low weed populations. Since the common soil condition in this part of Minnesota was high fertility and low weed pressure, the VICMS II data were important for producers interested in the transition from conventional practices to organic practices. Data from 1990 to 1999 were used in this study. Although they may differ from actual farm yields, the yields obtained in these research trials were considered the best comparison of different management strategies and cropping sequences, due to being obtained on the same location with all crops present in every year.

The three management strategies analyzed in this study used a low level of purchased inputs, a high level of purchased inputs and organic inputs. Both high and low levels were included, since the set of practices thought of as 'conventional' was similar to the high level of inputs at the beginning of the study, but had moved closer to the low level of inputs by 1999. A general description of each strategy is given below, with a general description of the production practices followed in each strategy listed in Table 1.

Low purchased inputs (LI)

Chemical applications were minimized by banding of fertilizers, banding of post-emergent herbicides (if needed), utilization of mechanical weed control, use of insecticides only if prescribed and similar practices. A realistic yield goal was used to determine fertilizer rates. This realistic yield goal was based on soil type, water availability,

Table 1. General description of the three management strategies: low purchased inputs (LI), high purchased inputs (HI), and organic inputs (OI)¹ for four crops.

	LI	HI	OI
Corn			
Prior fall tillage ²	None	Chisel	Chisel
Spring tillage	Field cul. (2×)	Field cul. (2×)	Field cul. (2×)
Rotary hoeing	1–3× (as needed)	None	1–3× (as needed) ³
Row cultivation	2–3×	1–3×	2–3×
Tillage after harvest	MB	MB	MB
Herbicides	Pre-e post.	Pre-e post.	Organic
Fertilizer application	Banded	Broadcast	Organic
Soybean			
Prior fall tillage	Soil saver	MB	MB
Spring tillage	Field cul./disk	Field cul./disk	Field cul./disk
Rotary hoeing	1–2×	None	1–2×
Row cultivation	2–3×	1–2×	2–3×
Tillage after harvest	None	Chisel	Chisel
Herbicides	Pre-e post.	Pre-e post.	None
Fertilizer application	Banded	Broadcast	Organic
Oat			
Prior fall tillage	None	Chisel	Chisel
Spring tillage	Field cul. (1×)	Field cul. (1×)	Field cul. (1×)
Rotary hoeing	None	None	None
Row cultivation	None	None	None
Tillage after harvest	None	None	None
Herbicides	None	None	None
Fertilizer application	Broadcast	Broadcast	Organic
Alfalfa			
Prior fall tillage	None	None	None
Spring tillage	None	None	None
Rotary hoeing	None	None	None
Row cultivation	None	None	None
Tillage after harvest	MB	MB	MB
Herbicides	None	None	None
Fertilizer application	Broadcast	Broadcast	Organic

Field cul., field cultivation; MB, moldboard plowing; Pre-e post., pre-emergent, post-emergent.

¹ Specific operations used each year may have been different.

² In the 4-year rotation the previous fall tillage was moldboard plowing (MB) of the alfalfa residue.

³ For the OI strategy, the fertilization was with fall-applied, composted beef manure for the 4-year rotation, and spring-applied swine manure for the 2-year rotation.

growing season length and actual recorded yields in the past, not an optimistic view of the soil potential.

High purchased inputs (HI)

Chemical applications were not necessarily minimized. Broadcast (no banding) fertilizers and insecticides were used according to university recommendations. Pre-emergent herbicides were often used. Other practices were selected on the basis of what were considered the best conventional practices for this region. An optimistic yield goal was used to determine fertilizer rates. However, even this optimistic yield goal was 'realistic' in that it, too, was based on actual recorded yields in the past, not an optimistic view of the soil potential.

Organic inputs (OI)

No synthetic chemical applications were used. Organic sources of nutrients, such as manure, and mechanical weed control were utilized. The OI strategy incorporated the best organic practices for the region, based on practices approved by a designated certification organization recognized by the Minnesota Department of Agriculture. The OI crops were not certified under NOP rules, but could have been. Potential organic premiums were not applied until certification was possible under organic certification standards (i.e. the third crop) in the 4-year sequence.

These three management strategies were carried out in two cropping sequences: the popular two-year sequence (corn–soybean) and a four-year sequence (corn–soybean–

Table 2. Typical harvest cash prices from the Southwestern Minnesota Farm Business Management Association (SW Ass'n) and all Minnesota (US\$ Mg⁻¹).

Crop	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Corn										
SW Ass'n	78.75	82.69	70.87	88.59	70.87	108.28	94.50	94.50	68.91	68.91
Minnesota	81.11	84.66	75.21	83.47	75.60	100.41	102.77	92.53	68.12	59.85
Soybean										
SW Ass'n	211.31	92.94	192.94	220.50	183.75	211.31	257.25	238.87	189.26	189.26
Minnesota	212.78	199.92	193.67	216.09	198.45	212.41	264.60	234.46	182.65	158.02
Oats										
SW Ass'n	86.13	68.91	68.91	86.13	75.80	103.36	137.81	137.81	82.69	82.69
Minnesota	72.35	68.22	83.38	88.89	74.42	94.40	135.06	103.36	67.53	60.64
Alfalfa										
SW Ass'n	66.15	55.13	60.64	77.18	77.18	77.18	88.20	104.74	71.66	71.66
Minnesota	104.74	73.32	88.48	105.01	82.41	80.21	92.61	115.49	88.48	72.49
Oat straw (US\$ bale ⁻¹)										
SW Ass'n	1.00	1.00	1.00	1.50	1.50	1.75	2.00	2.00	1.00	1.50

Sources: Adapted from annual association reports [e.g., Olson *et al.* (1992)⁷] and annual *Minnesota Agricultural Statistics* [e.g., Minnesota Agricultural Statistics Service (2001)⁶].

oat/alfalfa-alfalfa). Rotation restrictions did not allow the certification of a 2-year corn-soybean sequence as organically produced so, even though an organic management strategy was followed, crops grown under the 2-year sequence did not receive an organic premium in any year. Every crop in each cropping sequence was grown every year under each management strategy, so all treatments were present each year. Each combination of strategy and sequence was replicated three times in each year.

Data Collection and Analysis Methods

Detailed records have been maintained on field operations, labor used, rainfall, plant growth, weed counts (broadleaf and grasses separately), earthworm species and counts, mycorrhiza in the soil and plants, and crop yield. Soil phosphorus (P) and potassium (K) fertility levels were determined in the fall, and soil nitrate levels were determined in 0.304-meter increments to 1.52 m following alfalfa and soybeans.

The net return (NR) was calculated as gross income from the crops produced minus the direct production costs for each management strategy, cropping sequence and year. NR was expressed as the return per one hectare averaged over either two or four crops. The value of corn and soybean was included in NR for the 2-year sequence, and the value of corn, soybean, oat, oat straw, and alfalfa was included for the 4-year sequence. The gross income of each crop was calculated by multiplying the actual crop yield by the typical harvest cash price plus a potential organic premium (if applicable). The yield was the average of three replications. Typical harvest cash prices were those reported annually by the Southwestern Minnesota Farm Business Management Association (SWMFBMA, Table 2). Harvest prices were used (versus annual average prices) to

account for the value of production only and not for marketing skill. These SWMFBMA prices were used since they were considered to reflect more accurately the prices faced by farmers close to the VICMS study site, compared to using an overall Minnesota average price. Except for alfalfa and the oat price in later years, the SWMFBMA prices followed the annual levels and patterns of average harvest-time prices in Minnesota. Direct production costs were determined by the actual operations, input levels used and local input prices. The costs for land, management and indirect costs (farm insurance, marketing and so on) were not subtracted from the gross value of the crops because they would not vary between strategies and sequences. Thus, NR was the net return to land, management, indirect labor and other indirect costs for each management strategy and cropping sequence.

Production costs were estimated for each year using the actual cultural operations, equipment and inputs used, as listed in the research field records for each strategy and sequence. The cost of each operation was calculated using the University of Minnesota Extension Service's annual estimates of machinery costs, which included fuel, maintenance, repairs, operator labor and overhead costs of the machinery⁸. Each strategy and sequence was charged the same cost per pass for the same operation (cultivating, for example), but the total cost per hectare varied when the number of passes varied (two cultivations versus one cultivation, for example). Labor costs for machinery operations were included in extension's estimates, but since no records were kept to show differences in time required for pest scouting, managing, marketing and other indirect labor use, these labor costs are not included in the calculation of NR. Manure application costs were included in the organic systems, but no manure purchase cost was included. Local market prices were used for inputs except

for seed and herbicide. Seed costs were taken from annual SWMFBMA records⁷. Herbicide prices were taken from University of Minnesota Extension Service's annual weed control report⁹. Total crop production costs were the sum of tillage, planting, fertilizer, pest control, harvesting and hauling costs.

Due to insufficient annual information on organic premiums in Minnesota (and the US) for 1990 through 1999, potential organic premiums were estimated for corn, soybean and oat using information compiled by Dobbs and Pourier for 1995 through 1998¹⁰ (Table 3). Over these 4 years, the average price for certified organically produced corn was 160% of the average US cash price for non-organic corn; that is, the average premium for organic corn was 60% over the average non-organic corn. The average price for certified organically produced soybean was 236% of the average US cash price for non-organic soybean; that is, the average premium for organic soybean was 136% over non-organic soybean. The average price for certified organically produced oat was 163% of the average US cash price for non-organic oat; that is, the average premium for organic oat was 63% over the average non-organic oat. In the absence of reliable annual data on organic prices, these average organic premiums were applied to the typical harvest cash prices for corn, soybean and oat in the 4-year OI strategy, starting in 1992, the third year of production and the first that could be certified as organic. Production in 1990 and 1991 did not receive an organic premium because the land had not been in a certified organic production system for the required 36 months. This pattern of not applying organic premiums in the first 2 years but then applying them to eligible production in the third and following years simulated the transition a conventional farmer would have to go through to sell organically produced crops as certified organic. Due to lack of data, no price premium was considered for either organic alfalfa or organic oat straw. Because it would not meet NOP rules for certification, crops grown under the 2-year sequence did not receive organic premiums in any year, even though all other organic practices were followed. Using the same average organic premium for all years reduced the potential variability of NRs; however, the alternative of using annual premiums based on very little data seemed much less desirable.

Potential organic premiums vary from year to year and are also dependent on each individual producer's marketing strategies and abilities. To reflect this variability, three organic price scenarios were evaluated as well as the sensitivity to the oat straw price. In the first scenario (as discussed in the previous paragraph), corn, soybean and oat grown under the 4-year, OI strategy received the full historical average organic premium starting in the third year, i.e., 1992. The second price scenario was more conservative and assumed that eligible crops received only half of the historical average organic premiums starting in 1992 (or that only half of the eligible production received the historical average). The third price scenario contained

Table 3. Average organic price premium ratios based on organic price quotes and US cash prices.

Year	Corn	Soybeans	Oats
1995	1.35	2.14	1.35
1996	1.43	1.85	1.59
1997	1.73	2.41	1.73
1998	1.88	3.02	1.83
Average ratio	1.60	2.36	1.63
Average premium	60%	136%	63%
Half of the average premium	30%	68%	31.5%

Source: Dobbs and Pourier (1999)¹⁰.

Note: Due to insufficient data on organic prices for alfalfa and oat straw, no organic premiums were estimated for these two crop products.

no organic premiums even for certified organic production; every crop in every management strategy and sequence received the typical harvest cash prices reported earlier. This last price scenario was useful to evaluate the situation that may occur if a farmer could not obtain the organic premium or if the supply of organic production increased faster than the demand and put downward pressure on the organic premium. In all three price scenarios, non-organic crop production from the 2-year OI strategy and both sequences of the HI and LI strategies received only the typical harvest cash prices in every year. To evaluate whether the straw value would affect a farmer's choice of production method, the oat straw price was set to zero and NRs recalculated in a subsequent evaluation for all three scenarios.

Risk, that is, the variation in NR, was analyzed using stochastic dominance. Cumulative distribution functions (CDFs) of NRs were calculated based on the yields, market prices, input costs, potential organic premiums, correlations between crop yields and correlations between crop yield and market price. The CDFs were calculated using a program called Crystal Ball[®] (CB), which is an add-in program that functions within Microsoft's Excel[®]. Crystal Ball[®] was used to develop a probability distribution of net returns based on the averages and distributions of yields and market prices, average input costs, average potential organic premiums, correlations between crop yields, and correlations between crop yields and market prices. The distribution assigned to each individual crop yield within each strategy and sequence was based on actual recorded yield data, with the Kolmogorov–Smirnov (KS) test used to determine the best fitting distribution. Eleven distributions (Normal, Lognormal, Weibull, Triangular, Uniform, Beta, Exponential, Gamma, Logistic, Pareto, and Extreme Value) were considered. The top three best-fitting distributions (based on the KS test) were compared visually to the distribution of the actual yields as a visual check of their goodness-of-fit. For crop yields, 30 yield observations (3 replications/crop for 10 years) from each crop were used in fitting the distributions; if available, 33 observations from

Table 4. Price/yield correlations for each crop in each cropping sequence and management strategy from 1990 through 1999 in the VICMS II study.

Strategy	Corn 2-year	Soybean 2-year	Corn 4-year	Soybean 4-year	Oat 4-year	Alfalfa 4-year	Oat straw 4-year
LI	-0.847	0.059	-0.700	0.049	-0.252	-0.020	-0.525
HI	-0.683	-0.127	-0.734	-0.024	-0.341	-0.004	-0.525
OI	-0.197	-0.226	-0.557	-0.260	-0.314	0.091	-0.537

Source: Estimated from actual VICMS II experiment yield data and the prices listed in Table 2.

LI, low purchased inputs; HI, high purchased inputs; OI, organic inputs.

Table 5. Yield correlations for each crop in each cropping sequence and management strategy from 1990 through 1999 in the VICMS II study.

Strategy	Corn/SB 2-year	Corn/SB 4-year	Corn/oat 4-year	Corn/alfalfa 4-year	SB/oat 4-year	SB/alfalfa 4-year	Oat/alfalfa 4-year	Oat/oat straw 4-year
LI	0.643	0.558	0.369	-0.127	0.401	-0.479	-0.672	1.000
HI	0.713	0.456	0.353	-0.163	-0.080	-0.259	-0.570	1.000
OI	0.338	0.038	0.069	-0.180	0.328	-0.166	-0.667	1.000

Source: Estimated from actual VICMS II experiment yield data.

LI, low purchased inputs; HI, high purchased inputs; OI, organic inputs.

11 years were used. Using the same methods as for yields, crop price distributions were estimated using data from 1990 through 1999.

The total input cost of each crop in the risk analysis of the study was assumed to be constant, based on the actual historical 10-year average of input costs. Average projected costs were used since historical input prices, actual yields and field operations were used in the calculation of the yearly input costs. By using the 10-year average of input costs, it more accurately reflects the relationships and actual decisions made historically. Input costs in this part of the analysis were held constant because this is most likely the way individual farmers would represent their own costs in a similar forecasting or budgeting scenario. Potential organic premiums (i.e., ratios of organic prices to US cash prices) were also considered constants due to the lack of adequate data to estimate a sound distribution based on the historical data.

Correlations between crop yield and price were calculated using actual crop yields and their respective crop prices (Table 4). Correlations between crops were also calculated, using the actual recorded crop yields from the VICMS II data correlating the corn yield to other crops in the sequence (i.e., soybeans in the 2-year sequence and soybeans, oats and alfalfa in the 4-year sequence; Table 5).

Using the assigned distributions of crop yields and crop market prices, CB calculated 500 different possible random draw combinations of crop yields and prices. Using these 500 possible outcomes of yield and price, in addition to input costs and potential organic premiums, 500 possible outcomes of NR for each input strategy and cropping

sequence were also calculated. The 500 estimated NRs for each cropping sequence and input strategy were then used to develop their respective CDFs.

First-degree stochastic dominance (FSD) and second-degree stochastic dominance (SSD) were used to determine farmers' potential risk preferences between input strategies and cropping sequences¹¹.

Results

Annual corn and soybean yields in the 4-year sequences under the LI, HI and OI strategies tend to be equal to, or better than, the corn and soybean yields in the 2-year HI and LI strategies (Figs. 1 and 2). However, the average yields were not substantially different, except for the 2-year OI strategy, which had lower yields (Table 6). Although they are not shown, annual oat and alfalfa yields in all strategies followed very similar patterns. Only in 4-year OI corn could a potential transition period be seen due to its lower yields relative to other strategies (except 2-year OI); however, this period was uncertain, due to all strategies and sequences having lower yields in the fourth, extremely wet year. For other crops, the 4-year OI yields follow the annual patterns similar to other strategies (Figs. 3 and 4). Annual VICMS yields for all crops follow a similar pattern compared to the average yields reported for this part of Minnesota by the USDA. In most years, VICMS yields were higher than the USDA averages, with two exceptions. First, the organic yields (especially the 2-year rotation) were lower than average yields in this area. Secondly, the VICMS alfalfa yield was obviously higher in most years

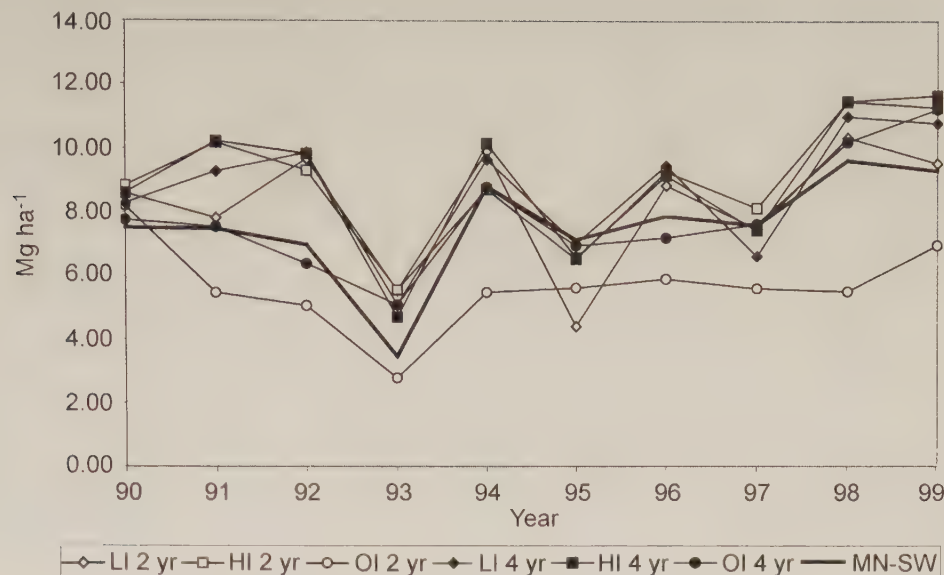


Figure 1. Corn yield by cropping sequence and management strategy, 1990–1999. LI, low purchased inputs; HI, high purchased inputs; OI, organic inputs; MN-SW, southwest Minnesota.

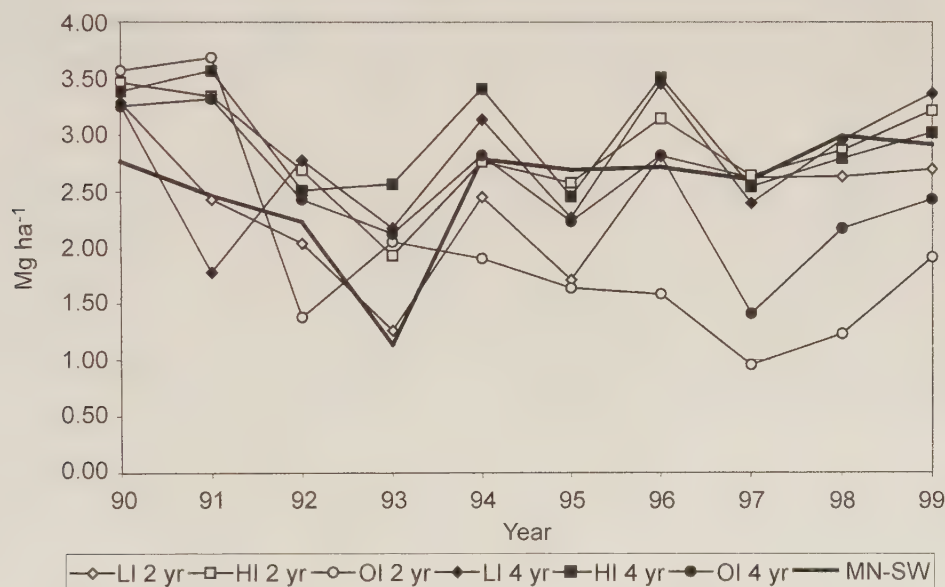


Figure 2. Soybean yield by cropping sequence and management strategy, 1990–1999. LI, low purchased inputs; HI, high purchased inputs; OI, organic inputs; MN-SW, southwest Minnesota.

than the USDA average. The higher alfalfa yields may be due to the VICMS study site being on better soils than most alfalfa fields in southwest Minnesota, and/or due to more management time spent on alfalfa within VICMS than an average farmer would spend. Porter et al. (2003)¹² provided a more detailed analysis of the agronomic results in the VICMS study.

Relative to the yields under conventional management, VICMS organic yields were similar to those obtained in other studies in the Midwest. In the VICMS II study, the 4-

year OI corn yield was 89% of the 2-year HI corn yield, and the 4-year OI soybean yield was 86% of the 2-year HI soybean yield. In a study at Iowa State, the 10-year average organic corn yield was 81% of the conventional corn yield; soybean was not included in the organic rotation². In Nebraska, the 8-year average organic corn yield was 85% of the conventional corn yield, and the 8-year average organic soybean yield was 84% of the conventional soybean yield². In South Dakota State, the 7-year average organic corn yield was 84% of the conventional corn yield

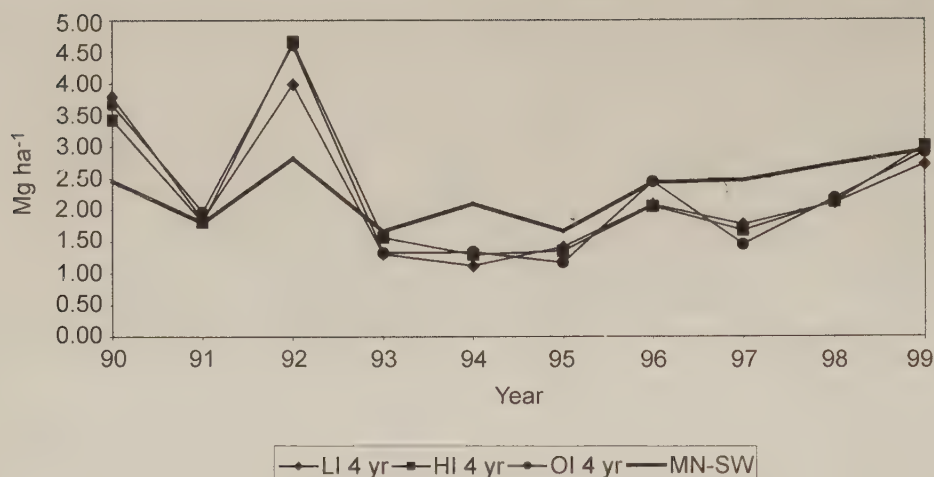


Figure 3. Oat yield by cropping sequence and management strategy, 1990–1999. LI, low purchased inputs; HI, high purchased inputs; OI, organic inputs; MN-SW, southwest Minnesota.

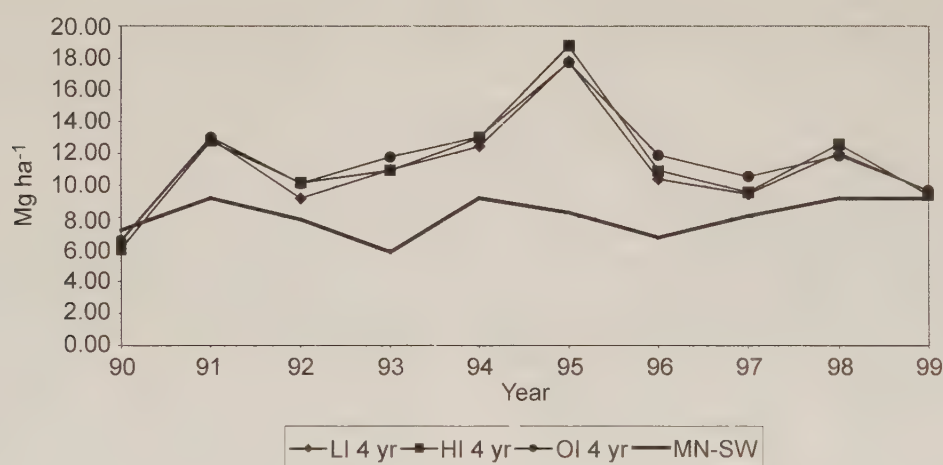


Figure 4. Alfalfa yield by cropping sequence and management strategy, 1990–1999. LI, low purchased inputs; HI, high purchased inputs; OI, organic inputs; MN-SW, southwest Minnesota.

Table 6. Average crop yields for each crop in each cropping sequence and management strategy from 1990 through 1999 in the VICMS II study (Mg ha^{-1}).

Strategy	Corn 2-year	Soybean 2-year	Corn 4-year	Soybean 4-year	Oats 4-year	Alfalfa 4-year
LI	8.22 (1.95)*	2.42 (0.58)	8.72 (1.92)	2.75 (0.57)	2.22 (1.00)	11.2 (2.01)
HI	8.90 (1.88)	2.89 (0.45)	8.97 (2.21)	2.96 (0.46)	2.29 (1.08)	11.4 (3.36)
OI	5.64 (1.38)	2.02 (0.93)	7.90 (1.79)	2.49 (0.57)	2.29 (1.14)	11.6 (2.91)

* Standard deviations are in parentheses.

and the 7-year average organic soybean yield was 99% of the conventional soybean yield².

In both the 2- and 4-year sequences, the HI strategy had the highest average direct production costs compared to the LI and OI strategies (Table 7). The OI strategy had the lowest costs. Direct production costs for

corn in the 2-year sequence averaged US\$116 higher per hectare under the HI strategy than under the OI strategy. In the 4-year sequence, the production costs for corn averaged US\$89 higher under the HI strategy than under the OI strategy. The variation between years was also higher for all crops under the HI strategy, as shown by

Table 7. Average crop production costs (US\$ ha⁻¹) for each crop in each cropping sequence and management strategy from 1990 through 1999 in the VICMS II study.

Strategy	Corn 2-year	Soybean 2-year	Corn 4-year	Soybean 4-year	Oats 4-year	Alfalfa 4-year
LI	291 (28.7)*	190 (16.3)	294 (28.7)	190 (18.0)	205 (32.1)	247 (41.7)
HI	358 (39.0)	203 (18.3)	351 (47.7)	217 (27.9)	222 (35.1)	257 (55.3)
OI	242 (16.5)	180 (24.0)	262 (13.8)	185 (14.3)	170 (16.5)	225 (35.3)

* Standard deviations are in parentheses.

Table 8. Average net returns for each crop in each cropping sequence and management strategy from 1990 through 1999 in the VICMS II study.

Strategy and pricing alternative	2-year sequence (US\$ ha ⁻¹)	4-year sequence (US\$ ha ⁻¹)
LI	339.4 (120.8) ^{b,c}	426.3 (91.1) ^b
HI	378.4 (108.4) ^b	423.9 (80.5) ^b
OI with average OP	— ¹	667.4 (188.2) ^a
OI with half the average OP	— ¹	550.1 (130.4) ^a
OI with no OP	227.7 (121.5) ^c	433.0 (84.5) ^b

OP, organic premiums.

¹Since the 2-year OI strategy did not meet the organic certification rules, it could not receive organic premiums.

Standard deviations are in parentheses.

Different letter superscripts indicate statistically significant differences between means ($P=0.05$).

the higher standard deviations. The lower costs for the OI strategy were primarily due to no expenditures for synthetic pesticides and chemically processed fertilizers, even though this strategy did pay more for additional mechanical weed control.

When full historical average organic price premiums (starting in the third year according to NOP rules) were applied to corn, soybean and oat grown under the 4-year OI strategy, the 10-year average NR was US\$667 per hectare (Table 8). This was significantly ($P=0.05$) higher than the HI and LI strategies in both the 2- and 4-year sequences. The 4-year HI strategy had an average NR of US\$424 ha⁻¹, and the 4-year LI strategy had an average NR of US\$426 ha⁻¹. The 2-year HI strategy had an average NR of US\$378 ha⁻¹, and the 2-year LI strategy had an average NR of US\$339 ha⁻¹. Although they look different, the average NRs for the 4-year HI and LI strategies were not significantly ($P=0.05$) different from the 2-year HI and LI strategies.

The 2-year OI strategy did not meet NOP rules for certification and, thus, could not receive any organic premiums in any year. Its average NR was US\$227 ha⁻¹, which was significantly ($P=0.05$) lower than any other strategy and sequence except for the 2-year LI strategy.

If only half the historical average organic premiums were received (or half of the production received the historical premium), the average NR for the 4-year OI strategy was US\$550 ha⁻¹. This was statistically equal

to the 4-year OI strategy when it received the full historical organic premium, but significantly ($P=0.05$) higher than all other strategies and sequences.

If the 4-year OI strategy did not receive any organic premiums, its average NR was US\$433 ha⁻¹. This was not significantly ($P=0.05$) different from the 4-year HI and LI strategies, and seemingly higher but not significantly ($P=0.05$) different from the NRs received from the 2-year HI and LI strategies.

The annual movements in the NR echo the similarities and differences noted in the averages just discussed. For clarity in the graph, only selected strategies and sequences were chosen to highlight the annual patterns (Fig. 5). The effect of starting to receive the organic premium in the third year was obvious as the annual NRs are substantially higher for the 4-year OI strategy compared to the other NRs. The higher levels of NR for the 4-year sequences can also be seen compared to the 2-year HI strategy.

When the oat straw price was set equal to zero for all 4-year sequences, the general level of NR decreased, but only one change in significance occurred. The only change was for the 4-year OI strategy with half of the historical organic premium, the NR of which became statistically ($P=0.05$) the same as the 4-year OI strategy with no premium and the HI and LI strategies in both the 2-year and 4-year sequence. Even with an oat straw price of zero, the NR for the 4-year OI strategy with the full historical premium remained

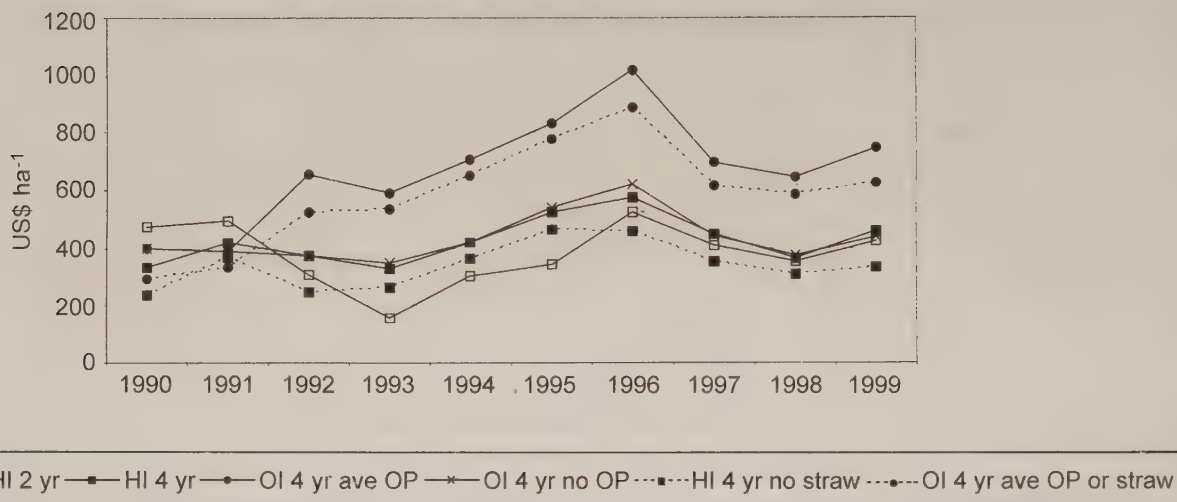


Figure 5. Annual net returns, selected strategies and sequences, 1990–1999. HI, high purchased inputs; OI, organic inputs; OP, organic premiums; ave, average.

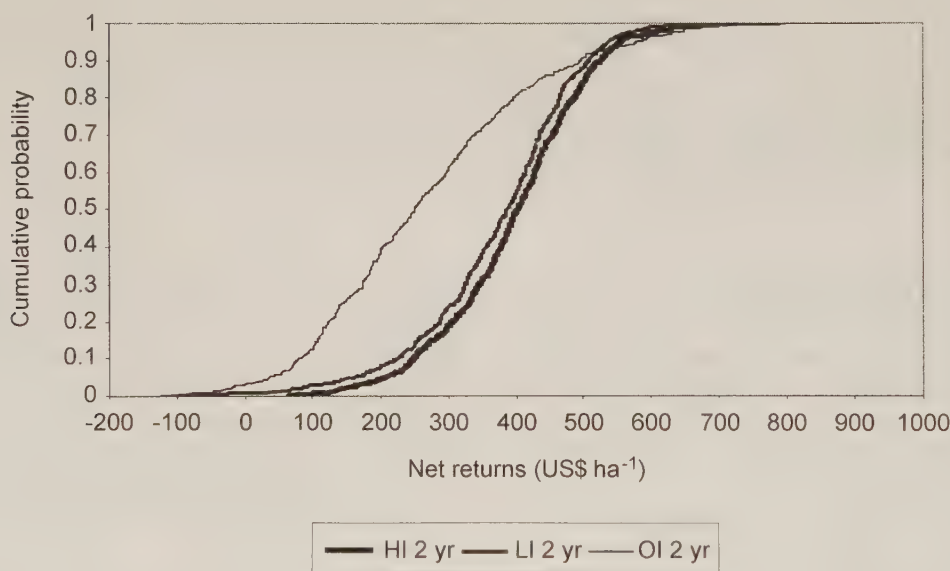


Figure 6. Cumulative distribution functions of net returns for low purchased input (LI), high purchased input (HI) and organic input (OI) strategies, 2-year sequence with conventional market prices.

significantly ($P=0.05$) higher than all other strategies and sequences.

When all input strategies received conventional prices in the 2-year sequence, both the HI and LI strategies dominated the OI strategy by SSD, and the HI strategy dominated the LI strategy by FSD (Fig. 6). Therefore, under the 2-year sequence, with all input strategies receiving the same market prices, the HI strategy would be preferred over the OI and LI strategies.

With all input strategies receiving the same conventional market prices (including the initial positive straw prices) under the 4-year sequence, the CDF of the OI strategy was equal to, or strictly below and to the right of, the CDF of

the HI strategy, thus dominating the HI strategy by FSD under the 4-year sequence (Fig. 7). Under the 4-year sequence there was no FSD or SSD between the OI and LI strategies. Although it is not clearly visible in Figure 7, the LI strategy had a lower NR than the HI strategy at a probability level of 1% or less (i.e., the CDF of the LI strategy begins to the left of the CDF of the HI strategy), therefore there was neither FSD nor SSD between the LI and HI strategies. However, starting at a probability level below 5%, the LI strategy had a higher NR at all probability levels.

With conventional market prices, the LI and OI 4-year strategies would be preferred to the 2-year HI strategy

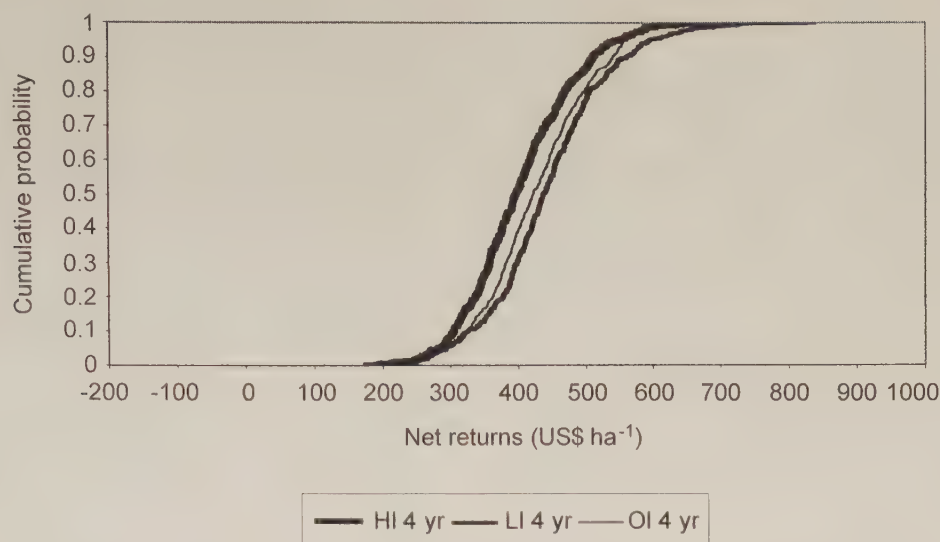


Figure 7. Cumulative distribution functions of net returns for low purchased input (LI), high purchased input (HI) and organic input (OI) strategies, 4-year sequence with conventional market prices and no organic premiums.

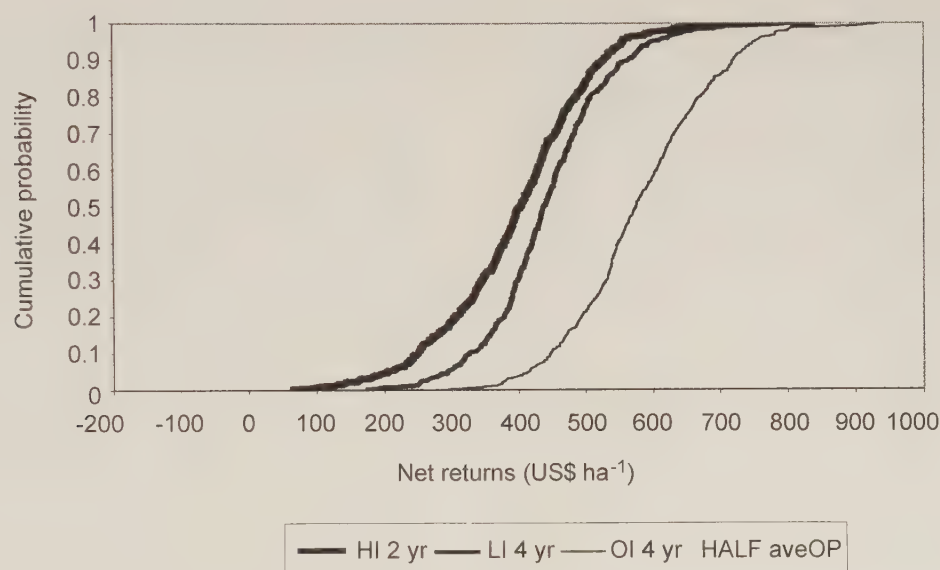


Figure 8. Cumulative distribution functions of net returns for 2-year high purchased input (HI) strategy and 4-year low purchased input (LI) strategy with conventional market prices and 4-year organic input (OI) strategy with half of the historic organic premiums (OP).

because they dominated the 2-year HI strategy by FSD and SSD, respectively. There was neither FSD nor SSD between the 4-year LI and 4-year OI strategies.

When the full organic premium for the OI strategy was added to the risk analysis under the 4-year sequence, the results of the OI strategy changed dramatically. The CDF of the OI strategy shifted notably to the right, and thus the OI strategy dominated the LI and HI strategies by FSD. The LI and HI strategies did not change since they were still receiving conventional prices, and thus there was still no FSD or SSD between the LI strategy and the HI strategy. Adding the full organic premium to the 4-year OI strategy

clearly made it the preferred strategy over all other input strategies and crop sequences.

Applying half of the historical average organic premiums to the OI crop in the 4-year sequence also resulted in the OI CDF moving notably to the right (Fig. 8). The 4-year OI strategy was again clearly below and to the right, and thus preferred to both the LI 4-year and HI 2-year strategies when applying half the premium to the 4-year OI strategy. In other words, the 4-year OI strategy with half of the historical average organic premiums had a higher NR at all probability levels than the 2-year HI and 4-year LI strategies with conventional market prices.

Conclusions

This research has shown the long-term impact on net returns of organic cropping strategies compared to conventional strategies. Even though crop yields were lower under the 4-year OI strategy, so too were its production costs. As a result, the 4-year OI strategy was able to produce NRs per acre statistically equal to the NRs under LI and HI strategies without any organic premiums, and significantly higher NRs when it received either full or half of the historical organic premiums. When the variability of NRs was analyzed using stochastic dominance, the 4-year OI strategy (with either full or half of the historical organic premiums) dominated all other strategies and sequences. When no organic premiums are applied, the 4-year LI strategy had higher NRs except at low probability levels (i.e., below 5%) although the CDFs are close visually. Based on these per-acre results, the original hypothesis of this study, that conventional agriculture (as represented by the HI and LI strategies) was more profitable and/or involved less risk than a 4-year OI strategy, must be rejected for this part of Minnesota.

This result, that conventional agriculture is not obviously more profitable or less variable on a per acre basis, supports the continuance of the current programs supporting organic farming, such as production research (including crop insurance coverage), market information and development, and policies at the federal and state levels. Policies that include subsidizing farmers for the environmental benefits of organic production methods warrant further development and refinement. Companies in the food-supply chain can continue to make investments to increase their capacity to handle organic products. Farmers and their advisors can be more confident in the potential benefits of investing the time and costs to learn the skills needed to grow and market certified organic products and to control potential problems.

Therefore, using the data from this study and the resulting profitability and risk analysis, the perception that conventional agriculture is more profitable, and/or involves less risk than a 4-year organic strategy, is not true for this part of southern Minnesota.

However, further research is still needed in several areas. This current study should be extended to include the VICMS trials that started on land with low fertility and high weed seed counts as well as the data from recent and future years. The NRs at the whole-farm level (versus the per-hectare calculations in the current study) should also be evaluated to estimate the impact of higher labor needs with organic methods. Further work is needed on the impact on crop prices and organic premiums of a substantial shift from the dominant corn-soybean sequence to longer cropping sequences. While considerable work has been done on consumer demand for organic products, more work is needed on the entire supply chain for organic products. Research is also needed on the feasibility of smaller

livestock production units on organic farms, as well as the availability and associated costs of obtaining organic manure from larger livestock units. Additional research is needed on organic production methods, including the feasibility of including green manures in the cropping system, organic weed control and cropping sequences other than those included in VICMS.

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The ability of organic farming to nourish the Austrian people: an empirical study in the region Mostviertel-Eisenwurzen (A)

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Abstract

A sustainable agricultural and food system is characterized by two qualities: availability of high-quality, healthy food along with the best possible preservation of natural resources. Organic farming is discussed as a solution model for the complementary achievement of both aims. Taking the region Mostviertel-Eisenwurzen (A) as a case study, the present investigation examines the regional self-reliance in food production by means of three scenarios. In the basic scenario, the current land use of the region is set against the present-day food demand of the local population. The organic scenario assumes that the farming method of the region adheres 100% to the guidelines of organic farming. The food produced is set against the current food demand, as in the basic scenario. In the third scenario—the organic-alternative scenario—the 100% organically produced food is set against a food demand of the local population that follows the recommendations of nutritional science, comprising more plant-based diets. The results show that in the case of the hypothetical conversion to organic farming, food production decreases in absolute numbers. Despite this reduction, the local population can be sufficiently supplied with food energy, both in the case of the average Austrian diet as well as in a diet according to the recommendations of nutritional science. The number of people that can be supplied outside the region is higher in the nutritional science diet than in the average Austrian diet, despite the lower total net export quantity. While egg, meat and milk production are up to six times the local demand, the degree of self-supply of plant products (especially fruit and vegetables) covers only two-thirds of the demand after conversion. Moreover, our calculations show how a change of consumption patterns affects the demand for imported feedstuff. The region changes from being a net importer of concentrate (76,190 t fresh mass) at the starting point to a gross exporter (39,784 t fresh mass) in the organic and the organic-alternative scenario. In summary, agricultural production according to the guidelines of organic farming and a diet following the recommendations of nutritional science seems a promising strategy for achieving a sustainable agricultural and food system.

Key words: organic farming, food security, food balance

Introduction

Food security, healthy food and the corresponding farming method have increasingly shifted into the public interest, due to the latest food scandals as well as to the increase of diet-related diseases. In particular, incorrect nutrition as far as quality is concerned is a phenomenon that plays a role not only in the so-called developing countries but also in the Western world. At the same time, food production in intensively managed farming systems frequently places massive pressure on the environment. Getting the agricul-

ture sector right is crucial for reducing this pressure on the environment, which is created throughout the entire food system¹.

Two objectives characterize a sustainable agricultural and food system. First, the availability of high-quality (i.e. with a higher content of valuable substances), healthy food (i.e. with a lower content of harmful substances) and, secondly, the simultaneous preservation of natural resources. Organic farming is being discussed as a model for the complementary achievement of both aims. Several scientific studies have pursued the question whether the

above-mentioned aims can be achieved by organic farming. The following authors examined the consequences of an extensive conversion to organic farming and see no threat to covering the domestic consumption in their countries: Langley *et al.* (1983)² for the USA, Bechmann *et al.* (1992)³ for Germany and Alroe and Kristensen (2001)⁴ for Denmark. On the other hand, Pommer and Rintelen (1997)⁵ predict shortages in oilseeds in the event of a partial conversion of Bavarian agriculture to organic farming. In a full conversion to organic farming, they predict shortages in the meat supply if meat consumption continues to remain high. Lampkin (1994)⁶ assumes that in Britain, provided the present-day consumption habits remain the same, the food supply from domestic production would be endangered at a conversion rate above 30% because national consumption would then exceed national production. For Germany, Seemüller (2000)⁷ calculates that converting the entire agricultural area to organic farming would be feasible without a need for additional farmland or imports, if the share of animal calories is reduced from an average of 39% to 24%; the latter value approximates Italian dietary habits. This aim can be achieved by 2024 if the present-day dietary trend continues (reduction in the share of animal products annually by 2.1% from 1990 to 1996 in Germany).

The present study estimates the consequences of an extensive conversion to organic methods on food production. It also develops a concrete alternative concerning food demand via altered consumption habits. Finally, the effects of an extensive conversion are set against the altered consumption patterns.

Region of Study

The region Mostviertel-Eisenwurzen is situated in the southwest of the Austrian Federal Province Lower Austria and covers an area of 3360 km² with a population of 238,000. The agricultural area amounts to 165,000 ha, 13% of which is managed according to organic farming guidelines. This proportion of organically managed area exceeds that in the rest of Austria. At the same time, conventional farming is intensive compared to other parts of Austria (high density of livestock, high proportion of maize).

Methods

Scenarios

The present study analyzes three scenarios.

Basic scenario. The present-day land use of the region Mostviertel-Eisenwurzen (87% of the agricultural area is managed conventionally, 13% organically) is compared with the food consumption of the population. In this scenario, consumption is defined as the average diet of the Austrian population. The underlying question is whether the population can be fully supplied with locally produced food, and how many additional people could be supplied,

given such consumption.

Organic scenario. The organic scenario differs from the basic scenario mainly in respect to the farming method: 100% of the production in the region is assumed to be organic. At the same time we assume that only food originating from organic farming is demanded by the local population. The produced food is also set against the Austrian present-day average consumption, as in the basic scenario. Here we also examine the number of people outside the region that can be supplied with food from this agricultural area.

Organic-alternative scenario. This scenario modifies the above organic scenario with respect to food consumption patterns. Instead of the average Austrian consumption pattern, the locally, organically produced food is compared to the recommendations of nutritional science. We investigated how many people within and outside the region can be sufficiently supplied with food after conversion to organic farming, if these people follow the recommendations of the food pyramid⁸.

Calculation scheme

Figure 1 outlines the methodology for the determination of both the local production of plant and animal products, as well as of the imports of plant products and feedstuffs. The crop areas of the single crops are multiplied by the respective yields, differentiating between organic and conventional production systems. From the thus-calculated gross production we subtract storage losses of cereals (–10%), potatoes (–15%), vegetables (–25%) and roughage (–5% to –15%; W. Knaus, personal communication 2002), as well as processing losses in the case of oilcrops⁹, to determine net production. The non-food crops or feedstuffs, such as renewable raw materials, are excluded from the net yield of crops (without field forage) and are omitted in the following calculations. While plant foods are consumed directly by humans, the other crops, together with the net yield of green forage and roughage, go into the calculation of the local feedstuffs production. In the following, the term ‘feedstuff’ comprises concentrates such as maize and grain as well as roughage. In a next step, livestock and animal performance—again differentiated between organic and conventional farming—are used to calculate the necessary imports of feedstuffs (taking locally produced feedstuffs into account). Finally, the calculated amount of plant and animal food is compared with the food demand of the local population.

Land use and livestock

Based on official statistics¹⁰, ten typical farm types of conventional and organic farming are determined by means of cluster analysis. These farm types comprise two different dairy farms, a suckling cow farm, a sheep farm, a fattening cattle farm, a fattening pig farm, a breeding pig farm, a poultry farm, a commercial farm and one mixed farm. The conversion to organic farming in scenarios 2 and 3 assumes

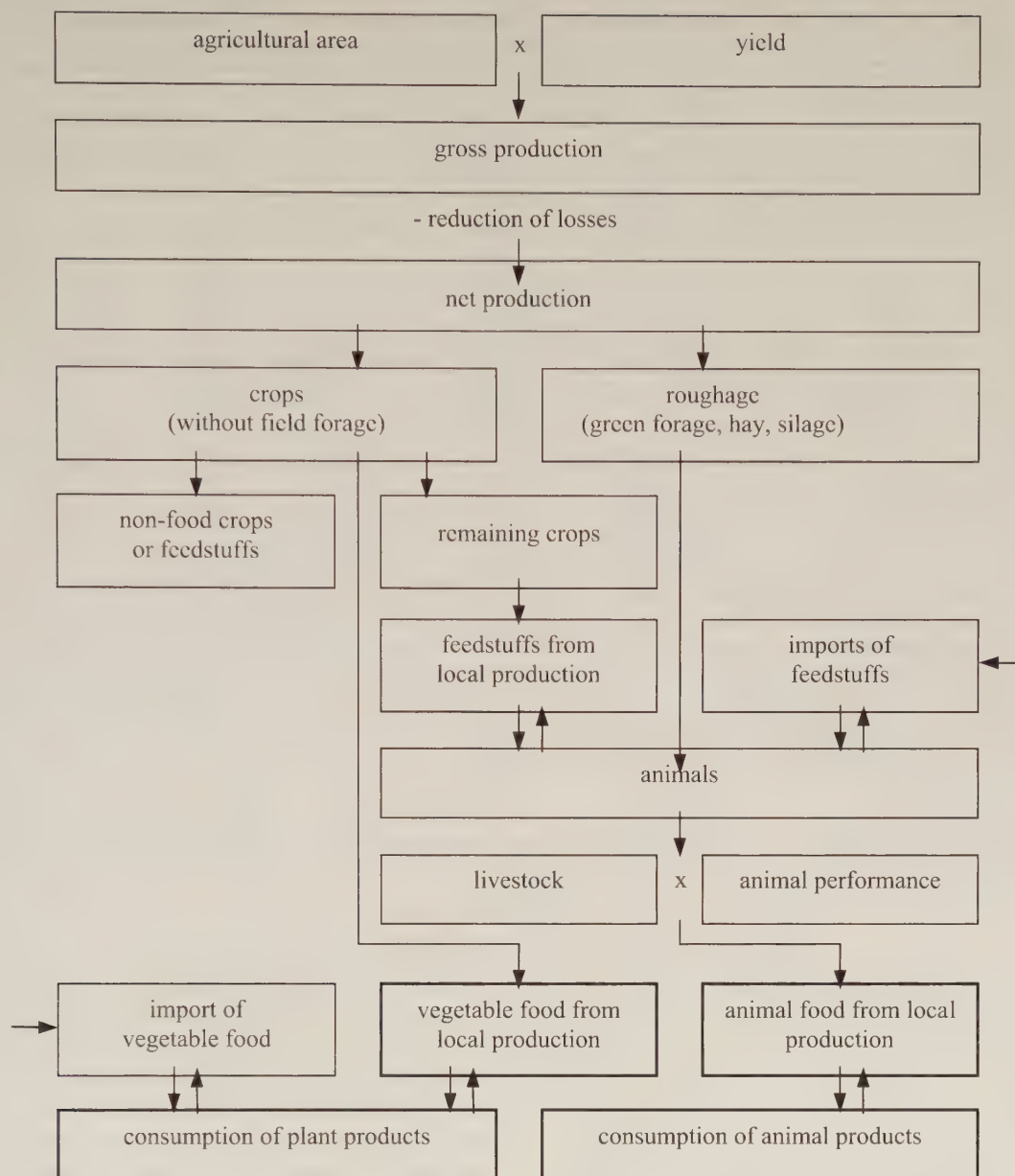


Figure 1. Calculation scheme. Bold frames = major results. Modified from Seemüller (2000)⁷.

that the farm types remain the same and that the partition of the cultivated area (grassland versus arable area) also remains the same. Within each of the ten farm types the use of the arable area and the livestock numbers of the organically managed cluster are transferred to the conventionally managed clusters. For this reason, in scenarios 2 and 3 the land use changes and livestock become reduced (Tables 1 and 2).

Food production

The gross production of plant products is calculated by multiplying the respective crop area with its yield, differentiating between conventional and organic production (Fig. 1). An analogous procedure is used for the animal production (livestock $\times$ animal performance). The amount

of plant and animal yields, as well as their reduction due to the conversion to organic farming, is deduced from various sources: from the literature^{12–39}, from local data^{40–42} and from author's own data collected on farms and from agricultural advisors of the region⁴³. We assume the following decrease in yield due to the conversion: –16% for field forage and intensively managed grassland (for extensive grassland yield remains constant), –15 to –32% for cereals, –32% for grain peas, –40% for root crops, and –50% for oil crops. For animal performance we assume: –10% of the milk yield, –25% of the slaughter weight in beef production (maintaining the same keeping duration), an increase of slaughter weight of pigs by +11% (increasing the fattening duration by +64%), and a decrease in laying performance of the laying hens by –9% (increasing the keeping duration by +10%).

Table 1. Change in the use of the agricultural area due to regional farming according to organic farming guidelines.

Crops	Basic scenario				Org. scenario and org.-alternative scenario		
	Conv. ha	Org. ha	Total ha	%	ha	Total	%
Agricultural area	143,955	21,472	165,427	100.0	165,427		100.0
Arable area	73,073	2,135	75,208	45.0	75,208		45.0
Grassland	70,882	19,337	90,219	55.0	90,219		55.0
Arable area							
Cereals ¹	30,895	883	31,778	42.3	36,071		48.0
Maize ²	22,607	106	22,713	30.2	5,275		7.0
Field forage ³	10,186	952	11,138	14.8	24,186		32.2
Grain legumes	3,335	90	3,225	4.3	5,562		7.4
Oil crops ⁴	2,331	41	2,371	3.2	1,804		2.4
Sugar beet	1,610	1	1,611	2.1	0		0.0
Potatoes and vegetables	246	33	279	0.4	677		0.9
Other ⁵	2,064	29	2,094	2.8	1,634		2.1
Grassland							
Extensive grassland ⁶	5,882	1,633	7,515	8.4	7,515		8.4
Intensive grassland ⁷	65,001	17,704	82,704	91.7	82,704		91.7

Org., organic; Conv., conventional.

¹ Wheat, spelt, rye, winter and summer barley, oats, mixed grain, triticale.

² Grain maize, corn cob mix, maize for silage.

³ Alfalfa, clover, clover/grass, temporary grassland, forage grasses.

⁴ Rape, sunflower, soya, oil squash.

⁵ Feeding beet, green fallow.

⁶ Meadows of one cutting, rough grazing, alpine pasture, other extensively used meadows. Extensive grassland also includes the region's 750,000 apple and pear trees, which are extensively managed. Intensive fruit production is not important in the region.

⁷ Meadows with multiple cuttings, litter meadows with stone fruit trees, meadows.

Sources: INVEKOS (1998)¹⁰, LFBIS (1999)¹¹, authors' own calculations

Production of and demand for feedstuffs

As explained in the Calculation scheme section, the amount of available, locally produced feedstuffs comprises the crops available for feed purposes (feeding grains, maize for silage, grain maize) together with the net yield of green forage and roughage. In the basic scenario, the demand of feedstuffs is calculated separately, according to conventional and organic cultivation methods, by multiplying the respective common feeding rations indicated in the literature for the various livestock^{44–48} and in expert opinions (W. Knaus, personal communication 2002; W. Zollitsch, personal communication 2002). For scenarios 2 and 3, the feeding rations of organic farming are adopted for all animals. These feedstuff demands are then compared with the regional feedstuff production. The difference between these two values represents the required imports of feedstuffs.

Food demand

For both the basic scenario and the organic scenario, the daily food requirements in kilocalories (kcal), according to the Food Balance Sheets of the FAO⁴⁹ are applied as a starting point. The total food consumption amounts to 3639 kcal person⁻¹ day⁻¹, with 67% of the energy being

vegetable food and 33% animal food. The diet recommendations for the organic-alternative scenario are based on the food pyramid, the recommendations of the Deutsche Gesellschaft für Ernährung (DGE) (ratio of 10:30:60 for protein:fat:carbohydrates, relating to the energy content of these nutrients) and literature recommendations concerning a reduction of animal food in favor of vegetable food^{50–57}. Table 3 shows how the recommendations differ in detail from the average Austrian diet according to the FAO⁴⁹, both in terms of the generally lower total energy supply (2300 kcal person⁻¹ day⁻¹) as well as the higher proportion of vegetable food. In the recommendations, 300 kcal person⁻¹ day⁻¹ are calculated for luxury food, i.e. sweets, tropical and subtropical fruit, alcohol, coffee and cocoa. This is approximately half of the actual consumption of this food group in Austria. Since most of these goods have to be imported, they are omitted from the further food production/food consumption comparison.

Results

Food production and demand

Table 4 sets food production and food demand of the three scenarios against each other. The self-supply data in the basic scenario demonstrate impressively that the study area

Table 2. Changes in livestock due to regional farming according to organic farming guidelines.

Animal species or specialization of production	Basic scenario			Org. scenario and org.-alternative scenario	
	Conv.	Org.	Total	Total	
	----- Head of stock -----			Head of stock	% of basic scenario
Cattle	106,279	15,554	121,832	105,165	86.3
Fattening calves (milk)	1,042	222	1,264	902	71.4
Fattening heifers	4,078	363	4,441	3,024	68.1
Fattening bulls	23,255	1,404	24,659	16,577	67.2
Dairy cows	58,320	8,562	66,881	66,881	100.0
Other cattle ¹	19,584	5,003	24,587	17,781	72.3
Pigs	306,570	2,398	308,968	128,762	41.7
Piglets	120,859	499	121,358	48,843	40.2
Gilts and fattening pigs	154,103	1,831	155,934	67,208	43.1
Breeding sows	31,608	68	31,676	12,711	40.1
Sheep	16,142	7,306	23,448	23,448	100.0
Goat	4,159	1,090	5,249	5,249	100.0
Fattening poultry	1,616,171	2,913	1,619,102	527,841	32.6
Laying hens	991,005	31,293	1,022,298	353,158	34.5
Turkey hens	68,530	950	69,480	16,090	23.2

Org., organic; Conv., conventional.

¹ Cattle and breeding cattle, suckling cows, yearling heifers.Sources: INVEKOS (1998)¹⁰, LFBIS (1999)¹¹, authors' own calculations.**Table 3.** Current versus recommended consumption of various food products.

Food product	Current consumption		Recommended consumption		Recommendation in % of current consumption
	kcal person ⁻¹ day ⁻¹	g person ⁻¹ day ⁻¹	kcal person ⁻¹ day ⁻¹	g person ⁻¹ day ⁻¹	
Cereals	910	313	1026	353	113
Potatoes	115	182	104	165	91
Sugar, sweetener ¹	452	123	37	12	8
Legumes	8	3	17	6	215
Nuts	37	16	0	0	0
Oil crops	34	9	0	0	0
Vegetable oils	402	44	463	51	115
Vegetables	68	272	105	412	154
Fruit ²	108	228	299	645	277
Plant products total	2134		2051		96
Meat	421	253	89	53	21
Animal fat ³	333	51	146	20	44
Milk	358	765	275	588	77
Eggs	50	36	50	35	99
Fish	21	39	15	27	69
Animal products total	1183		574		49
Food total	3317		2625		79

¹ Recommended consumption only honey.² Without bananas, pineapple and citrus fruits.³ Recommended consumption only butter.Sources: Cleveland et al. (1997)⁵¹, DACH (2000)⁵⁴, Buhmann and Berweger (2001)⁵⁵, FAO (2001)⁴⁹, US FDA (2001)⁵⁶, WHO (1998)⁵⁸, authors' own assumptions.

Table 4. Production, demand and degree of self-supply of various products in the three scenarios.

Product	Basic scenario			Org. scenario			Org.-alternative scenario		
	Production	Demand ¹	dss ³	Production	Demand ¹	dss ³	Production	Demand ²	dss ³
	-- kcal person ⁻¹ day ⁻¹ --		%	-- kcal person ⁻¹ day ⁻¹ --		%	-- kcal person ⁻¹ day ⁻¹ --		%
Plant products	2,402	2,134	113	1,336	2,134	63	1,336	2,051	65
Cereals	1,503	910	165	1,229	910	135	1,229	1,026	120
Potatoes	34	115	29	51	115	44	51	104	49
Sugar, sweetener ⁴	684	452	151	0	452	0	0	37	0
Legumes	0	8	0	0	8	0	0	17	0
Nuts	0	37	0	0	37	0	0	0	
Oil crops	0	34	0	0	34	0	0	0	
Vegetable oils	169	402	42	43	402	11	43	463	9
Vegetables	9	68	13	9	68	14	9	105	9
Fruit ⁵	4	108	4	4	108	4	4	299	2
Animal products	3,260	1,183	276	2,292	1,183	194	2,292	575	399
Meat	1,114	421	265	481	421	114	481	89	542
Animal fat ⁶	0	333	0	0	333	0	0	146	0
Milk	1,880	358	525	1,730	358	483	1,730	275	628
Eggs	265	50	530	81	50	163	81	50	164
Fish	0	21	0	0	21	0	0	15	0
Total	5,662	3,317	171	3,628	3,317	106	3,641	2,625	194

¹The demand is calculated by multiplying the average Austrian consumption in t person⁻¹ year⁻¹ (from FAO, 2001⁴⁹) by the population figures of the region Mostviertel-Eisenwurzen (approx. value: 238,000).

²The demand is calculated by multiplying the consumption according to the recommendations of nutritional science in t person⁻¹ year⁻¹ by the population figures of the region Mostviertel-Eisenwurzen (approx. value: 238,000).

³dss = degree of self-supply = production as a percentage of the demand.

⁴The production includes solely sugar in the basic scenario; the requirements include solely honey in the organic-alternative scenario.

⁵Bananas, pineapple and citrus fruit are not included because they cannot be produced in the region (included under luxury food in this study).

⁶The production of animal fat is contained in other groups such as meat, and the demand includes solely butter in the organic-alternative scenario.

Source: authors' own calculations.

qualifies as a food export region at the starting point. This applies in particular to animal products, where production exceeds local demand by 176%. As regards vegetable food, local demand is only slightly exceeded; here, greater surpluses exist only for cereals and sugar beet. In case of a regional land use according to organic farming guidelines (with unchanged dietary habits), the degree of self-supply concerning both vegetable food all food groups decreases dramatically. This is because, compared with the basic scenario, sugar-beet production ceases, meat and egg production drops by approximately one-third, and vegetable-oil production decreases by three-quarters. The situation in the organic-alternative scenario is different. On the one hand, the degree of self-supply regarding vegetable food (only 65%) is low, as in the organic scenario, and, on the other hand, the production of animal food greatly exceeds the demand. With a degree of self-supply of 399%, these data exceed the comparative value of the starting situation (basic scenario) by 123 percentage points.

Likewise, the degree of self-supply for all food groups combined exceeds that of the basic scenario.

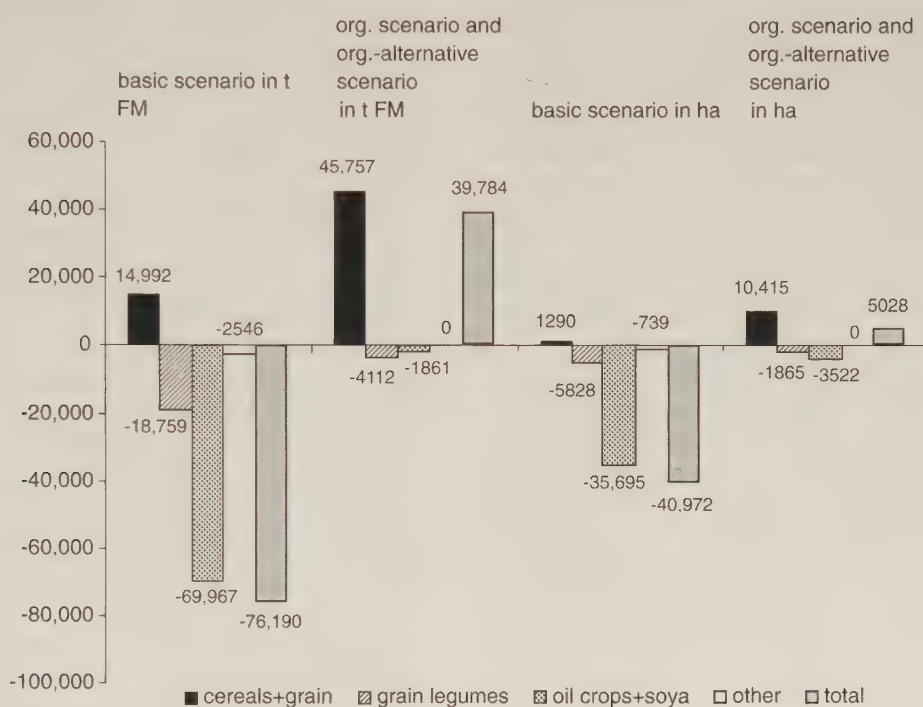
Export potential of food

The changes in food production, food demand and degree of self-supply in the scenarios correspond to the theoretically available regional export potential. In absolute numbers, the potential exports decrease due to the lower production of many products after conversion. The net export quantity potential (exports minus necessary imports for the local population) decreases in the organic scenario (201,742 t) versus the basic scenario (294,210 t) by approximately one-quarter, and decreases again slightly in the organic-alternative scenario (195,877 t, see Table 5) due to the increasing import demand for fruit and vegetables. How does this affect the number of people outside the region that can be supplied by the regional agriculture? Assuming the same dietary habits as the local population, this number decreases for cereals in scenarios 2 and 3 due to lower production in organic farming, or due to the locally higher demand related to altered dietary habits, respectively (Table 5). Sugar-beet production ceases completely after the conversion and the export potential therefore drops to zero. The export potential of animal

Table 5. Number of people from outside the region that can be supplied with food from the region under the three scenarios.

Food product	Basic scenario	Organic scenario	Organic-alternative-scenario
----- net export quantity in t fresh mass -----			
Food products total	294,210	201,742	195,877
net export quantity in number of people that can be supplied outside the region			
Cereals	155,034	83,934	47,438
Sugar	122,192	—	—
Meat	391,941	33,730	1,052,837
Milk	1,012,084	911,821	1,257,259
Eggs	1,024,560	149,294	153,067

Source: authors' own calculations.

**Figure 2.** Import demand for feedstuffs (-) and export potential for feedstuffs (+), as well as the theoretically required or available cultivable area in the scenarios. Org., organic; FM, fresh mass. Source: authors' own calculations.

products mirrors the supply within the region (Table 4). While the lower value for scenario 2 is due to the conversion of the farming system, the potential export quantity of scenario 3 exceeds by far the comparative value, due to altered demand, in particular for milk and meat.

Import demand for feedstuffs

In calculating potential food exports, one must consider that production, especially in the case of intensively managed farming systems, involves the use of both renewable and non-renewable resources from outside the region. In the case of large-scale imported feedstuffs, the transportation issue and their predominant origin from so-

called Third World countries are problematic ecologically and sociologically. Figure 2 shows that the comparatively high net exports of food in scenario 1 (Table 5) go hand in hand with a high import of feedstuffs. Oil cake, oil meal and soybeans (defined as oil crops and soya in Fig. 2), which together already amount to more than 90% of the imported feedstuffs in the basic scenario, take up 35,695 ha of arable area outside the region (Fig. 2). This corresponds to 15 times the arable land used for the production of feedstuffs in the region itself! Based on the conversion of agricultural production to the organic farming method in scenarios 2 and 3, the region changes from being a feedstuffs importer to being a feedstuffs exporter, due to the heavily reduced demand for feeding grains and the phase out of oil meal.

Conclusions

This study shows that a hypothetical conversion of the intensively managed farmland in the region Mostviertel-Eisenwurzen (A) to organic farming would decrease the total food production. Despite this reduction, however, the local population can be supplied sufficiently with food energy, both in the case of an average Austrian diet and a diet based on the recommendations of nutritional science. Therefore, the feared shortage of supply reported in the literature can not be confirmed. More food is currently produced than consumed in Austria. From a national point of view, a slight reduction in the food production does not create a food security problem. In the region studied, production exceeding the local demand is none the less desirable, in order to guarantee the supply for densely populated areas whose population is dependent on external supply. The Mostviertel-Eisenwurzen region can contribute to this supply. The organic and organic-alternative scenarios show that people outside the region can also be supplied with cereals, milk, meat and eggs after the conversion. The number of outside people supplied is higher in the 'nutritional science'-recommended diet than in the average Austrian diet, despite the lower total net exports.

Examining the production numbers of single products or product groups shows a distinct disproportion between plant and animal products. While eggs, meat and milk are produced up to six times the local demand, the self-supply of plant products is only 63% (organic scenario) or 65% (organic-alternative scenario) after the conversion. Fruit and vegetables, especially, are produced in insufficient amounts to cover local demand. The same holds true for feedstuffs. Grain legumes are cultivated in insufficient amounts in all three scenarios, whereas grain maize exhibits surpluses. Altered land use and reduced livestock could ameliorate the demand and supply imbalances investigated in the scenarios. Reduced livestock and the resulting lower demand for feedstuffs would enable plant products to be cultivated on a larger part of the agricultural area for direct human consumption. This would better fill the demand for plant products, a demand that none of the scenarios could cover. In addition to these suggested production-related changes, the calculations show that altered consumption patterns affect the demand for feedstuff imports. The region changes from being a net importer of concentrate (76,190 t fresh mass) at the starting point to a gross exporter (39,784 t fresh mass) after the conversion to organic farming.

In summary, agricultural production according to organic farming guidelines and a diet following the recommendations of nutritional science represent a favorable combination that enables local supply of most of the required food. This combination is therefore a promising strategy on the way to a sustainable agricultural and food system.

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The technology adoption behavior of women farmers: The case of alley farming in Nigeria

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Research Paper

Abstract

The indigenous system of crop production in Nigeria, the bush fallow farming system, which is known for its stability and biological efficiency, can no longer be operated effectively, due to a shortage of land. In order to increase farm productivity, researchers have devised alley farming, a low-input farming system which sustains crop and livestock production, can reduce competition from weeds, and conserves soil by reducing soil physico-chemical degradation and the decline of soil organic matter. The mobilization of women to adopt agricultural innovations is an important topic in development studies. Due to the important role of Nigerian women farmers in crop and livestock production, they are encouraged to adopt alley farming. Contrary to some of the literature, which claims that women are slow innovation adopters, this study argues that women farmers easily adopt innovations that can enhance their economic status. The paper argues that the characteristics of alley farming influence women farmers' adoption or rejection of the farming system. It was observed that the land tenure system is not an inflexible constraint on alley farming adoption. It is argued that low participation of women in agricultural innovation adoption is caused by lack of information about the advantages of the innovations, because meetings are fixed at times when women are not able to attend. This paper points out that the adoption of alley farming has increased the agricultural production and the quality of life of women farmer adopters.

Key words: alley farming, sustainable agricultural techniques, rural development, adoption of agricultural innovations, women farmers, factors affecting adoption

Introduction

An important challenge facing researchers in developing countries is the urgent need to devise a sustainable farming system able to improve soil fertility, optimize land use and maintain long-term farm productivity at a low cost. Due to urbanization and a high farming population, the bush fallow system can no longer be practiced effectively. Extensive land use has led to reduction in the fallow period and land degradation. Therefore, in order to sustain yield at the present level and possibly to increase it, the use of fertilizers was introduced into farming. To encourage fertilizer usage, the Nigerian government stepped up the importation of chemical fertilizers and also built a chemical plant to meet anticipated demand. The demand for fertilizer increased sharply, resulting in the spending of much hard-

earned foreign exchange to import fertilizers. In 1985, 1.1 million tonnes of chemical fertilizers were imported by the Nigerian government¹. Initially fertilizers were highly subsidized by the government; later the subsidy was reduced. Since the reduction of the subsidy, Nigerian farmers have to spend much money on fertilizers, resulting in the price being beyond the reach of farmers, especially smallholder farmers, who constitute the bulk of the Nigerian farming population. In 1986 a metric tonne of fertilizer cost about N100 (approximately US\$200, or N5 per bag; N represents Naira). By the year 2003, a metric tonne cost N40,000 (approximately US\$307, or N2000 per bag) (personal communication via email with Dr. Simi Odeyinka, 2003). The increase in price is mainly due to the devaluation of the Naira against the US dollar—a 39,900% increase in price over a period of 15 years. To worsen the

situation, the high prices prevail during the planting season and they are still on the increase. Many writers have pointed out that fertilizer residues are destructive to the environment, in particular to the soil structure²⁻⁴ and the quality of water resources^{5,6}, leading to increased degradation of the productive capacity of the life-support systems on which farmers depend, i.e., the land. The result is shortage of food², which may lead to increased poverty. It is apparent that a sustainable farming system is needed which does not rely on the application of fertilizers, which has a low cost, is consistent with the socio-economic and technological practices of the farmers, and can sustain production and maintain soil fertility.

Researchers at the International Institute of Tropical Agriculture (IITA) and International Livestock Research Institute (ILRI) [formerly known as the International Livestock Centre for Africa (ILCA)] in Ibadan, Nigeria carried out research on alley farming. Alley farming is a farming and agroforestry system in which fast-growing leguminous trees are planted in hedgerows with crops cultivated between them^{4,7-9}. Alley farming allows continuous cropping¹⁰, increases agricultural production, helps in poverty alleviation, eliminates the bush fallow system, combats weeds¹¹ and is considered by some a soil conservation measure, reducing soil degradation and organic matter decline^{11,12}. Before alley farming can be effectively adopted, there is a need for long-term investment in land, but the indigenous land tenure system does not recognize the right of many women to own land. Since Yoruba women farmers are cash-crop and food-crop producers and are the main producers of livestock, there is a need to identify the constraints to their adoption of alley farming, which is a profitable and sustainable technology.

Although other writers^{13,14} have studied the factors that influence alley farming adoption, no study has empirically identified the factors that determine women farmers' adoption of alley farming. The objectives of this study were: (1) to examine the effects of the characteristics of alley farming and those of women farmers on the women's adoption of alley farming; and (2) to investigate the effect of customary tenure rules and practices on women farmers' adoption of alley farming in Oyo state, Nigeria. Strategies are suggested for achieving increased adoption of alley farming by women farmers.

Alley Farming

IITA developed alley cropping. ILCA added livestock production to alley cropping by utilizing part of the foliage as fodder for livestock, calling the system alley farming. When two types of leguminous trees are used in alley farming, they are planted 4 or 5 m apart in alternate rows and 40–50 cm apart within the row. The trees are pruned and used as mulch and livestock feed. Alley trees can grow on degraded land and restore nutrients to the land due to their deep rooting pattern¹². Alley farming combines many

agricultural activities, such as tree planting and management, crop production, livestock husbandry, and land and soil management. IITA and ILRI scientists found that the most suitable hedgerow species in southwestern Nigeria are *Leucaena leucocephala* and *Gliricidia sepium*. These trees perform the same function as observed in the bush fallow system. They yield large quantities of nitrogen when grown in hedgerows in alley farming systems^{15,16} and fix 100–300 kg N ha⁻¹ yr⁻¹ or more⁹. Alley trees yield the largest amount of nutrient (400 kg N ha⁻¹ yr⁻¹), show higher nutrient recycling capabilities than other woody species and are well suited for alley farming in the humid and subhumid tropics. They are able to pass nutrients slowly to the subsoil because of their deep roots; the nutrients are then absorbed by food crops. *L. leucocephala* is the most efficient of the common alley tree species in maintaining soil organic matter^{4,17-21}.

Alley farming not only allows higher intensity of land use, but also improves soil fertility at a low cost, thus reducing or eliminating the need for chemical fertilizers. It can therefore be regarded as a bush fallow system that combines cropping and fallow phases. Alley farming has some characteristics that can be found in the indigenous agricultural system. For example, Nigerian farmers are familiar with bush fallow systems and they utilize leaves for mulch. On the other hand, alley farming involves new farming practices. These farming innovations, according to Atta-Krah and Francis (1987)²², include the planting and establishment of trees within arable farms, their management for mulch and fodder production, cut-and-carry feeding for animals, and the alteration of land-use and rotation patterns.

Alley farming is an innovation that can overcome the problem of land degradation, which is a pressing problem in tropical Africa^{23,24}. The functions of alley farming include maintenance of soil fertility through nitrogen fixation and nutrient cycling; maintenance of adequate levels of soil organic matter; supply of mulch for protecting the soil and regulating water infiltration, run off and erosion; supply of fuelwood; supply of stakes and ligneous materials that can be put to industrial use; supply of browse or fodder for animal feed; and limitation of fallows to narrow strips, consequently saving land and making continuous farming possible^{9,24-26}.

It is sometimes argued that alley farming is not beneficial, due to the fact that alley trees are not planted for direct economic benefit to the farmers in terms of harvested produce; there are no edible fruits from alley trees. Economically, alley farming is profitable to farmers because it enables high crop yields at low cost and allows continuous cropping²⁷. Alley farming encourages sustainability of rural development. Its adoption facilitates the sustainability of farmers' environment and income.

Methodology

Data collection

The study was conducted in southwestern Nigeria in November 1990. Primary data were collected through the field survey of Yoruba women farmers in seven villages: Iwo-Ate, Owu-Ile, Alfa, Oke, Iyana Ofa, Ofa-Igbo and Arikuyeri. In Owu-Ile and Iwo-ate, there are about 172 households, with an average of 3.6 adults per household. The population density of the other villages is between 138 and 404 people per square kilometer. Many farmers cultivated small farms in the study area. Twenty-five percent cultivated 0.5 acres of land, 60.7% had between 1 and 3.5 acres of land, 13.8% had 4–7 acres and 0.6% had 8 acres. The average farm size is 1.92 acres. The villages have a bimodal rainfall regime. The average annual rainfall in Owu-Ile and Iwo-Ate is 1700 mm while the average annual rainfall in the other villages is over 1800 mm. The bimodal pattern of rainfall in the villages allows two cropping seasons in a year. The first season is between April and June and the second is between July and October.

The villages were selected intentionally so as to incorporate those villages where alley farming has been introduced. The women farmers were interviewed by trained research assistants using modified structured and unstructured interview schedules. The sample size was 168. The sample includes both women adopters and non-adopters of alley farming. As few understood English, questions were asked in the local language but responses were recorded in English. In order to achieve accuracy in the data collection, secondary information was gathered through official statistical reports and personal observations. The author visited some of the alley farms of adopters, who told her their views about alley farming. Information was also gathered from persons known for their expertise on the customary land tenure system and alley farming.

The main occupation in all the villages is agriculture. Men and women cultivate the land. Some women worked on their husband's farm and harvested the crops, while many women had their own land, were independent farmers, cash-crop producers and main producers of livestock. They were farm managers, decision-makers and owners in their own right²⁸. Of the women farmers surveyed, 86.9% were managers of their livestock in their own right and 86.3% made decisions on their own regarding the management and disposition of their crops. Women also engage in other economic activities, such as food processing, trading, sewing, selling clothes and poultry farming. Moreover, women own most of the small ruminants such as sheep and goats. Women also practice caretaking of small ruminants. Livestock are allowed to roam unrestricted in these villages. Small ruminants, especially sheep and goats, are owned by most households. Farmers in the villages engage in the bush fallow rotation system, with 3–4 years cropping and only

3–4 years fallow. Land shortage is a problem in the study area. The major crops include cassava, yam and maize, which are interplanted with many minor crops, i.e., peppers, tomatoes, okra, cowpeas, cocoyams, banana and other vegetables. These crops are grown for marketing. Some farmers grow peppers, cocoyams, tomatoes and vegetables for consumption.

There are differences between men and women in terms of their access to land through the land tenure system. Men acquire land through inheritance, but not all women have the right to land through inheritance. Women's access to land differs across families. Whereas some Yoruba families do not allow women to inherit land, others grant equal rights to both male and female children. If all the children are female, they have the right to inherit land from their fathers. In some families, wives have the right to allocation of land through their husbands, and they can plant any type of crop on such land. The main qualification for land ownership is lineage membership. Two categories of qualified women were identified. The first include those women who have the right to land in their lineage and those who can inherit land from their parents in the absence of any male offspring of their parents. The second category are those who have access to land through their husbands. Usually the husbands inform their family members of their wives' intention to use part of the family land.

One of the problems facing agriculture in the villages is the migration of some able-bodied men to cities in search of waged work. This has resulted in a reduction of food production.

The Pearson correlation coefficient was used to determine the strength and direction of the linear relationship between the dependent and the independent variables. The Pearson's level of significance used was one-tailed and the significance level less than 0.01. The dependent variable was women farmers' level of adoption. This was operationalized by using three levels of adoption, namely awareness, trial and adoption. Farmers were asked to indicate the stage at which they were. Farmers in the awareness stage were those who had heard about alley farming but had neither tried nor adopted it. Those in the trial stage were those who had heard and were trying it on a small scale but had not adopted it; and those in the adoption stage had adopted it. These levels were arranged in an increasing order, and numerical values were assigned to each. Those farmers in the awareness stage were assigned 1 point; trial, 2 points; and adoption, 3 points. The independent variables were factors affecting adoption of alley farming, which were effect of customary land tenure system on women's access to land, socio-economic characteristics of the farmers, and the characteristics of alley farming. Membership in an organization was one of the farmers' characteristics that was tested. They were asked: 'Do you belong to any organization?' They were asked to mark Yes or No. The farmers who answered Yes were assigned 2 points while those who said No were assigned 1 point.

The characteristics of an innovation include its relative advantage, compatibility, complexity, triability and observability. Respondents were given some statements that measure the characteristics of the innovation. For example, for relative advantage they were asked: 'Do you agree that alley farming is better than the farming system you were practicing before?' They were asked to select, for each statement, one of five response categories which were scored according to the intensity of agreement with statements that are favorable to innovation characteristics. The response categories were scored as follows: Strongly Agree, 5 points; Agree, 4 points; Neutral, 3 points; Disagree, 2 points; and Strongly Disagree, 1 point.

Data were analyzed using the Statistical Package for the Social Sciences for Personal Computer SPSSPC, version 4.10, developed by SPSS Inc., USA. Percentages, frequency counts, chi-square test and bar charts were used in this study.

Results and Discussion

Levels of adoption

Six (3.6%) of the women farmers had not heard about alley farming before, while 96.4% had heard about it. Grouping the women cultivators into three levels of adoption, namely awareness, trial and adoption; 55.6% were in the awareness stage and 0.6 % in the trial stage, while 43.8% were in the adoption stage. Only one respondent was in the trial stage of alley farming, and it was not certain whether she would adopt alley farming or not. This respondent was excluded from the rest of the analyses, due to small sample size. It is observed that many of the women farmers did not adopt alley farming. When asked to give the reasons why, lack of information about the benefits of alley farming (21.0 %) and lack of money (19.8 %) were the two major reasons given. Information about alley farming was not communicated effectively to women. Meetings were fixed at times when it was not convenient for women to attend. The main village contacts, the researchers and the extension workers were men²⁹.

Factors affecting the adoption of alley farming

Characteristics of alley farming. The characteristics of an innovation affect its adoption. Kinnucan et al. (1990)³⁰ point out that the characteristics of agricultural innovations influence farmers' decisions regarding adoption. It does not matter whether or not the inherent characteristics of an innovation are better than those of the idea it is replacing; what matters is whether the farmer sees the advantage of the innovation to be superior to current practices. An innovation can be characterized in several dimensions, namely its relative advantage, compatibility, complexity, triability and its observability³¹.

Relative advantage. Relative advantage is the degree to which a new idea or practice is superior to the idea or

practice it is intended to replace. The relative advantage is expressed in terms of cost, social prestige, convenience and satisfaction. Sheth et al. (1999)³² asserted that the relative advantage of an innovation determines its adoption. The price of an innovation affects its rate of adoption and use; the higher the price, the lower the rate of adoption³⁰. The relative advantage of alley farming in a society or community depends on land availability, and fertilizer and feed prices. The benefits of the farming system are likely to be realized sooner by a farmer using chemical fertilizer than one who is not using it. Alley farming has been found to be more profitable than indigenous bush fallow systems^{4,33}. According to Kang and Shannon (2001)⁴, alley farming is more advantageous than the bush fallow system because of its continuous cropping, thus eradicating a fallow phase and land clearing. Alley farming has a labor-saving potential, and this may make it an attractive farming system in Africa where the land/labor ratio is high³³.

Compatibility. Compatibility means the extent to which an innovation is consistent with the farmer's existing community values, traditional management objectives and existing levels of the farming system³¹. Farmers may reject the capital-intensive technology of advanced economies due to its incompatibility with the existing level of farm technology. On the other hand, they may easily adopt appropriate technology because of its compatibility with their values. Due to some similarities between alley farming and bush fallow systems, farmers in Nigeria may not find it difficult to adopt alley farming. For instance, indigenous Nigerian farmers planted crops and woody species on the same piece of land. Moreover, traditional farmers in the lesser Sudan Islands of southeastern Indonesia and southern Philippines have practiced alley farming for a long time⁹. Farmers in these area are likely to adopt alley farming. Farmers in developing countries whose farmlands have deteriorated due to use of foreign technologies are adopting technologies that are consistent with their indigenous practices, as a means of restoring their farmland.

Complexity. Complexity is the relative ease or difficulty with which the farmer can understand and use the innovation. Alley farming is easy to learn³⁴. Foreign mechanical devices may be difficult for farmers to operate and may not be easily adopted.

Triability. Triability is the extent to which an adopter can test the innovation on a limited scale. Rogers (1995)³⁵ points out that some innovations are more difficult to divide for trial than others. Kang and Shannon (2001)⁴ assert that alley farming can be cultivated on a small area and produce an annual crop.

Observability. Observability concerns the degree to which the results of an innovation are visible to farmers. An innovation is more likely to be adopted if its advantage can

easily be seen. Farmers need to conserve the fertility of their land, but the initial time lag in deriving benefits, that is the time taken for the leguminous trees to grow, may be a constraint for them in adopting alley farming^{33,36,37}.

The data reveal that there was a positive and significant relationship between the characteristics of alley farming and the farmers' level of adoption of alley farming (Table 1). The coefficients for level of adoption and the relative advantage of alley farming in terms of its cost (−0.8291), social prestige (0.8182), convenience (0.8431) and satisfaction (0.8493) were slightly higher than those of its compatibility with existing community values (0.7680), traditional management objectives (0.7596) and existing level of farming system (0.7607). Moreover, there was a high positive and significant correlation between women farmers' level of adoption and the complexity of alley farming (0.8458), its triability (0.8637) and its observability (0.8671). The largest percentage of adopters, 73.2%, agreed that alley farming is consistent with their existing level of farming system, compared with only 2.2% of the non-adopters who agreed that it is. Moreover, 14.1% of the adopters strongly agreed, while none of the non-adopters strongly agreed. These findings support IITA (1989/90)³⁸, which states that farmers readily adopt innovations that they consider are compatible with their existing level of farming system.

Women farmers who said that alley farming is cheaper than their former farming system are more likely to adopt it than those who did not. This benefit may be seen easily by farmers who have formerly used chemical fertilizers, which are very expensive in Nigeria. In contrast to fertilizer, alley trees can gradually increase production with minimal investment. This is because, ideally, farmers purchase their initial seed stocks at a cheap rate, or they may be given free. Farmers can get their seed supplies from each successive harvest. As a result, they only need to make the planting investment and to multiply the seeds. Whereas, in the case of fertilizer, farmers require more capital to acquire fertilizer due to its high cost and scarcity in Nigeria. Moreover, fertilizer is a non-seed innovation, and its adoption involves recurring costs which result from input

consumption and replacement requirements. Furthermore, chemical fertilizer increases yield in the short term whereas alley farming increases production for the long term, although alley farming requires a longer time to start yielding³⁹. In addition, the cost of labor for clearing new land in the case of farmers who practice the bush fallow system is very high. Such farmers may find that alley farming is cheaper and may result in saving part of their labor costs. Although some women are assisted by their children in clearing the land, this may be restricted by school attendance.

Characteristics of women farmers. The study of adopters often includes the effect of their personal and socio-economic characteristics, such as age, level of formal education, level of income, marital status, size of farm, extension contacts and membership in an organization, on their adoption of innovations.

Age. Two contrasting views have been expressed by researchers on the relationship between the age of the farmer and adoption behavior. Some researchers claimed that age affects adoption, while others have said that there is no relationship between age and adoption. Kinnucan *et al.* (1990)³⁰ observed that there is a relationship between age and farmers' adoption behavior. Some studies have emphasized highest adoption at middle age. Younger farmers are said to be more interested in making changes in farming, so they are more likely to adopt new ideas than older farmers. As shown in Figure 1, the age group 31–39 years had the highest percentage of adopters (46.48%).

Formal education. The level of formal education of women may be a predictor of their adoption of innovations. Some studies have emphasized a positive association between formal education and adoption^{30,40}. The assumption is that schooling facilitates learning which, in turn, is presumed to instill a favorable attitude towards the use of improved farm practices⁴¹. On the other hand, Cramb and Nelson (1998)³⁴ believed that education is not important in explaining adoption. In most cases, whether an individual has a formal education or not has no relationship with his or her adoption behavior.

Table 1. Correlation between farmers' level of adoption and the characteristics of alley farming.

Characteristics of alley farming	Correlation coefficient (r)
Its cost	−0.8291
Social prestige derived from adopting it	0.8182
Its convenience	0.8431
The satisfaction derived from adopting it	0.8493
Conformity with existing community values	0.7680
Conformity with traditional management objectives	0.7596
Conformity with existing level of farming system	0.7607
Its relative ease or difficulty	0.8458
Possibility for its trial on a limited scale	0.8637
Extent to which its advantages can easily be seen	0.8671

The values of 'r' are significant, with one-tailed significance levels less than 0.01.

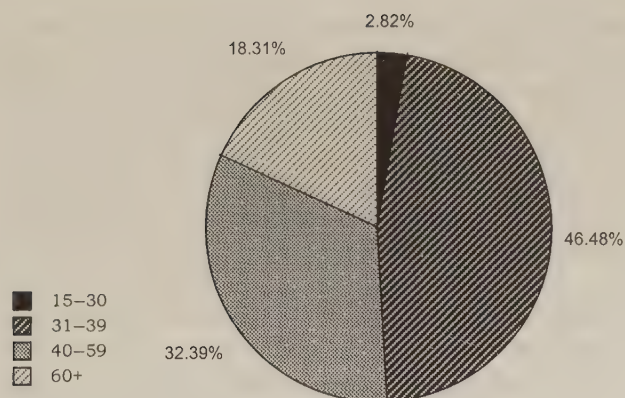


Figure 1. Adopters according to age group.

Level of income. Many research findings have shown an important relationship between level of income and adoption of innovation. Kinucan *et al.* (1990)³⁰ claimed that farmers possessing a high level of income make better use of innovative farming techniques. The higher the level of income of a farmer, the more he or she can afford to take financial risks, because he or she can offset losses from some of the less successful experiments.

Marital status. In their study on the adoption of alley farming by women farmers, Francis and Atta-Krah (1988)⁴² discovered that there is a relationship between marital status and adoption of alley farming by women. Married women are said to participate more actively than single women in projects that can increase their income. Women whose children go to school are assumed to readily adopt new agricultural practices so that they can better finance the post-primary education of their children.

Size of farm. There is positive relationship between farm size and adoption^{34,40,43}. Some researchers found no association between size of farm and farm practice adoption⁴⁴. Discussing the Green Revolution in Asia, Jabbar (1990)³³ stated that although the technology was originally characterized as scale neutral, larger farms became early and major adopters.

Extension contact. Agricultural extension services help in disseminating information about agricultural innovations to potential adopters, thus enhancing innovation adoption. In their study, Adesina *et al.* (1999)¹⁴ found out that the rate of adoption is higher among farmers who had contact with extension agencies.

Organization membership. Membership in organizations, for example farmer cooperatives and village societies, is an important farmer's characteristic that promotes adoption of new agricultural practices⁴⁵.

Correlation coefficients (r) were computed for the women farmers' level of adoption and their characteristics, namely level of formal education, size of farm, age,

Table 2. Respondents' age group by their level of adoption.

Age group	Level of adoption			Total
	Awareness	Trial	Adoption	
15-30	5 (71.4%)		2 (28.6%)	7 (100.0%)
31-39	55 (62.5%)		33 (37.5%)	88 (100.0%)
40-59	20 (46.5%)		23 (53.5%)	43 (100.0%)
60 and above	10 (41.6%)	1 (4.2%)	13 (54.2%)	24 (100.0%)

extension contact and membership in an organization, in order to discover the relationship between the variables. Among the correlation coefficients, only the coefficient between farmers' level of adoption and level of formal education was negative and non-significant (-0.0905). This indicates that the level of formal education of the women farmers was not related to their adoption behavior. Size of farm and level of adoption were positively and significantly correlated (0.5717). Moreover, with increased farm size, there was an increased propensity for women farmers to adopt alley farming. There was a positive and significant correlation between farmers' level of adoption and farmers' extension contact (0.5393) and membership in organizations such as farmer cooperatives and village societies (0.3483). Women farmers who adopt alley farming were more likely to belong to an organization than non-alley farmers, although the relationship between membership in an organization and level of adoption was weak. Also, there was a low positive and significant correlation between farmers' level of adoption and age (0.1891). From Table 2, age group 60 and above were more likely, as a percentage of their total (54.2%), to adopt alley farming. This age group was followed by age group 40-59 (53.5%).

The marital status of the farmers, as a factor affecting alley farming adoption, was examined (Table 3). The majority (74.7%) of alley farming adopters were married, 1.4% were single, 2.8% were divorced, 21.1% were widowed and none were separated. The only single woman adopted alley farming. One of the respondents was separated but she did not adopt alley farming. Fifty percent of those who were divorced adopted alley farming, 41.1% of the married women adopted the technology and 57.7% of the women who were widows adopted the technology.

Customary land tenure system. The customary land tenure system is the right of individuals and of groups in a social system that regulates their use and control of the system's land resources.

The majority of the women farmers surveyed (57.2%) did not have access to land through the customary land tenure system. As shown on Table 4, the largest percentage of the adopters (47.9%) in the sample disagreed that the tenure system allows them to have access to land, and 45.1% of them agreed. These findings show that those who do not have access to land, through the land tenure system, can adopt. The

Table 3. Distribution of respondents by marital status and level of adoption.

Level of adoption	Single		Married		Separated		Divorced		Widowed		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Awareness	—	—	76	84.5	1	1.1	2	2.2	11	12.2	90	100.0
Adoption	1	1.4	53	74.7	—	—	2	2.8	15	21.1	71	100.0
Total	1	0.6	129	80.1	1	0.6	4	2.5	26	16.2	161 ¹	100.0

¹ 161 = number of women adopters and non-adopters of alley farming.

Table 4. Respondents' level of adoption by their opinion on the effect of customary land tenure system on their access to land: Do you agree that the customary land tenure system allows you to have access to land?

Level of adoption	Effect of customary land tenure on access to land											
	Strongly agree		Agree		Neutral		Disagree		Strongly disagree		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Awareness	1	1.1	29	32.2	3	3.3	53	59.0	4	4.4	90	100
Adoption	2	2.8	32	45.1	2	2.8	34	47.9	1	1.4	71	100
Total	3	1.9	61	37.9	5	3.1	87	54.0	5	3.1	161 ¹	100

¹ 161 = number of women adopters and non-adopters of alley farming.

findings contradict the literature on women's access to land through the land tenure system and their adoption behavior, which states that women who do not have access to land through the land tenure system may not adopt agricultural innovations. The disadvantaged status of women in having access to land, through land tenure systems, does not hinder them from adopting alley farming. A similar result was obtained by Adesina et al. (1999)¹⁴ in their survey conducted in Cameroon, Nigeria and Benin. Women who do not have access to land through land tenure can lease or purchase land.

Impact of alley farming on women adopters

When asked about the benefits they derived from alley farming, many women adopters in the sampled villages claimed that alley farming has improved their crops and livestock production. A similar result was obtained by Isaac et al. (2003)¹¹ in their study conducted in Haiti. In the study area, the Nigerian women adopters indicated that they derived higher income from the sale of their crops and livestock, and this has improved their quality of life. They declared that alley trees maintained the soil fertility at low cost, thus minimizing the cost of their farm maintenance. Their livestock were healthier when fed with alley trees. These were consistent with the results reported by Kang et al. (1999)⁹, Kang and Akinnifesi (2000)⁴⁶ and Isaac et al. (2003)²⁴. None of the adopters had stopped alley farming. They claimed that alley farming is a profitable technology.

Conclusions

Many Nigerian farmers are facing serious problems of land shortage which is caused by urbanization and the extensive use of land. This has led to rapid deterioration of the soil structure. The application of large amount of fertilizers to farmland has led to land degradation. Farmers need sustainable and more productive farming systems. Sustainable land use is that which achieves production combined with conservation of the resources on which production depends, thereby permitting the maintenance of productivity⁴⁷.

Alley farming can lead to sustainability of rural development. It can maintain soil fertility through nitrogen fixation and nutrient cycling. Isaac et al. (2003)¹¹ claimed that alley farming is a soil conservation measure. Alley farming can counteract many adverse conditions, such as weed growth¹². It is capable of protecting the soil from erosion. Alley farming is acceptable to small farmers because it is not an expensive farming system. It is a sustainable alternative to the bush fallow system. Unlike imported complex technology, alley farming is 'appropriate' and is 'within the ability' of small farm holders to manage; it is also 'compatible with their financial capabilities'. Its ability to increase crops and livestock production and to produce usable materials in years of severe drought enhance its adoption by women farmers who are producers of cash crops and livestock.

The characteristics of alley farming influence the decision of the women farmers to adopt it. There is a

positive and significant relationship between the relative advantage, compatibility, complexity, triability and observability of alley farming and its adoption by women farmers. The personal characteristics of women farmers, such as size of farm, extension contact and membership in organizations, are positively and significantly correlated with farmers' level of adoption, while their level of formal education is not related to their adoption behavior. Women's lack of access to land through the customary land tenure system does not hinder their adoption of alley farming.

Recommendations

Researchers should focus on what may be termed 'needs identification', which means they try to recognize exactly the farmers' felt needs and design technologies that can meet their needs. This can enhance farmers' willingness to adopt agricultural technologies. Many women farmers were not aware of the benefits of alley farming and were, therefore, not motivated to adopt it. In order to increase women's rate of adoption of alley farming, four things must be done. First, innovation messages must be effectively extended to women; secondly, meetings must be fixed at times when women will be able to attend, and women should be involved in the decision-making process; thirdly, the research and extension teams should include women, simply because many women farmers prefer to communicate with female researchers and extension workers; and finally, female research associates should be posted to the villages in order to inform the women about the benefits of alley farming and to find out those cultural factors that can enhance women's adoption of alley farming.

Land is an essential element in agricultural production. Many women did not have access to land through the land tenure system. The government should create an avenue whereby women can borrow money to purchase land.

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Book Review

Ecocide: A Short History of the Mass Extinction of Species. By Franz J. Broswimmer. 2002. Pluto Press, London UK and Sterling VA. xii + 204 p. \$69.95, ISBN 0-7453-1935-1, hardcover; \$24.95, ISBN 0-7453-1934-3, paperback.

Ecocide, a neologism coined by Franz Broswimmer, is defined as an act of intentional destruction or degradation of the environment. It is the cumulative sum of ecocidal acts that has resulted in the present, catastrophic loss of species around the globe—what Richard Leakey and Roger Lewin have recently termed the Sixth Extinction, since the rate and magnitude of contemporary species losses are similar to the five previous catastrophic mass extinction events documented in the fossil record.

The first four chapters of *Ecocide: A Short History of the Mass Extinction of Species* comprise a sweeping environmental history of humans, beginning with our hominid ancestors. Broswimmer paints a grim picture of accelerating species loss and environmental degradation, beginning with the late Pleistocene extinctions of large animals caused by early modern human hunters, then expanding through the extensive alteration of the Earth's surface caused by the spread of agriculture, then further worsened by the overexploitation of species resulting from the rise of capitalism and global trade networks, and finally culminating in the profound changes to global biogeochemical cycles and climate, and in toxification of air, water and soil, caused by the industrial revolution and the globalization of modern warfare. *Ecocide* covers much of the same material first presented by George Perkins Marsh in the 19th century, and more recently by Jared Diamond and Alfred Crosby.

Franz Broswimmer's stated intention in reviewing the environmental history of humans is to show how human cultural evolution, including technological advances and increases in the complexity of human social organization and social interchange, has resulted in the ongoing mass extinction event. He argues, correctly I believe, that the only way out of our present environmental crisis is to understand our current social institutions, and implement a strategy to reorganize them into forms that make it possible to attain a sustainable environment.

His suggestion is to reorganize human society toward something called 'ecological democracy'. Ecological democracy, as presented by Broswimmer, is primarily focused on expanded democratic decision-making and global social justice. Reduced consumption is acknowledged as important for attaining environmental sustain-

ability, but is given less emphasis than the goals of global equity and social justice. His most useful proposal, in my opinion, is for conservation scientists and environmental advocates to become better sociologists, thus acquiring the tools to inquire how institutions and individuals create different conceptions of 'interests', and how these conceptions might be modified to include concern for future generations of humans and other species by modifying the social systems within which we live.

Ecocide had its origins as a doctoral dissertation, and retains the structure of one. The main text of the book is only 105 pages, but an additional 100 pages are devoted to a detailed glossary, 35 tables, several hundred footnotes, the bibliography, and the index. Much of this extra material is quite peripheral to the main argument of the book.

The writing is crisp and the jargon is kept to a minimum. Unfortunately, the book is replete with scientific errors; it really could have used some careful reviewing by an ecologist. For example, the author repeatedly refers to the *late Quaternary* when he means *late Pleistocene*; he uses *plankton* when he means *protozoa*, *Aridipecus* when he means *Ardipithecus*. He states that polar bears were extirpated from New England in the 19th century; that martin, fisher and wolverine were driven extinct by the commercial fur trade; that several species of whales no longer exist due to overexploitation by whalers; and, most surprisingly, that 'the lemur' became critically endangered due to massive aerial bombing and application of chemical defoliants during the Vietnam war!

Ecocide: A Short History of the Mass Extinction of Species is a jeremiad that also succeeds in making some reasonable suggestions on how we might alter present social structures in ways that reduce our impact on other species. Social scientists who are unfamiliar with the history of human-caused extinctions and environmental degradation may find this short book useful, as may environmental scientists who are unfamiliar with the sociocultural influences on human behavior that have resulted in mass species extinctions. The book provides a wealth of data and interesting anecdotes about past and present human activities that have resulted in species loss. However, given the number of factual errors that I detected, I would recommend checking the sources of the data and anecdotes for accuracy before repeating them.

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